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Hunt for a Lunar Volcano

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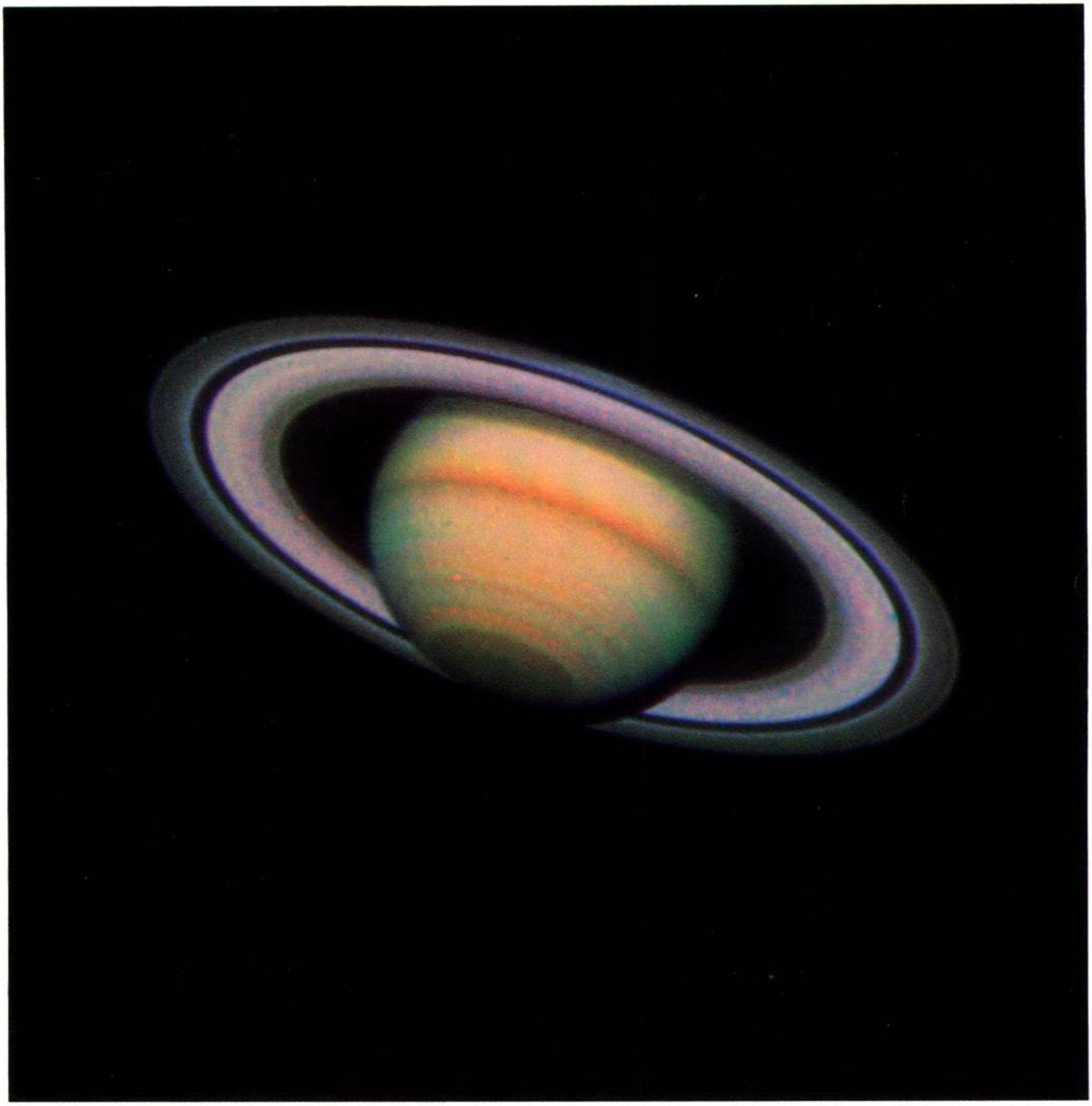

A Stunning Saturn from Hubble

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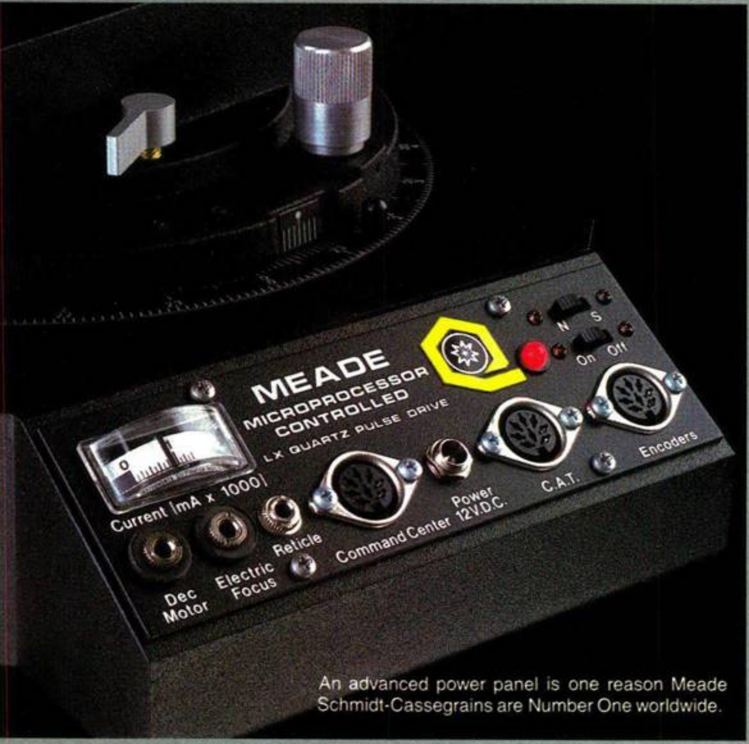

An advanced power panel is one reason Meade Schmidt-Cassegrains are Number One worldwide.

Using technology developed for the Meade 16″ Schmidt-Cassegrain, the Smart Drive yields observatory drive accuracy on all Meade Premier Series 8″ and 10″ SCT's:

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- **Meade Smart Drive technology reduces worm gear periodic error by up to 90%,** enabling vastly easier long-exposure astrophotography, with far fewer required corrections and fewer chances for guiding errors.
- **The Smart Drive is now available on all Meade 8″ and 10″ Premier Series Schmidt-Cassegrains**—from the budget-priced 8″ 30-Series to the advanced 10″ 70-Series, and on every model in between.
- **Using optional CCD's currently available,** the Smart Drive can be programmed to yield periodic errors as low as 1 arc sec.!
- **Previous Meade 8″ and 10″ Schmidt-Cassegrain models** may be upgraded to the Smart Drive—see your Meade dealer for details.
- **For complete information on the Meade Smart Drive**—and a point-by-point comparison with competing models—send $3.00 for your copy of the Meade 1990 Catalog #90C.

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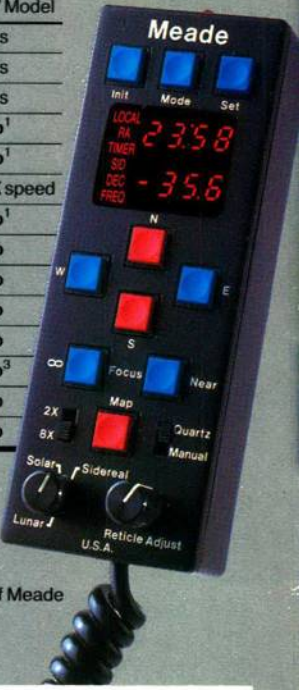
	Meade 8″ 2080/Model 50	Competing 8″ Model
North-South Operation	Yes	Yes
Map Light	Yes	Yes
2X Corrections East-West	Yes	Yes
2X Corrections North-South	Yes	**No**[1]
Declination Motor	Yes	**No**[1]
RA Slewing	8X speed	**4X** speed
Declination Slewing	8X speed	**No**[1]
Continuously Variable Freq. Control	Yes	**No**
Illuminated Reticle Control	Yes	**No**
Optional Digital Readouts	Yes[2]	**No**
Encoder Outlet	Yes	**No**
AC and DC Adapters	Yes	**No**[3]
Ammeter	Yes	**No**
CAT™ Computer Outlet	Yes	**No**

[1] Optional Dec. motor priced at $170 additional. [2] Includes digital coordinate readouts; digital timer; RA freq. display with King rate; local time; sidereal time. [3] Optional adapters priced at $58 additional.



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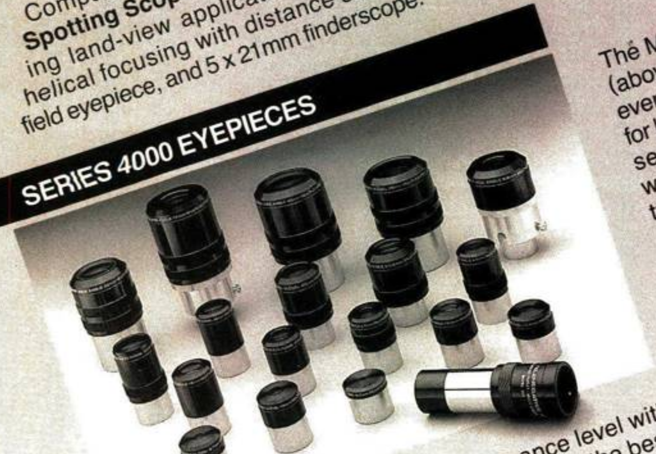

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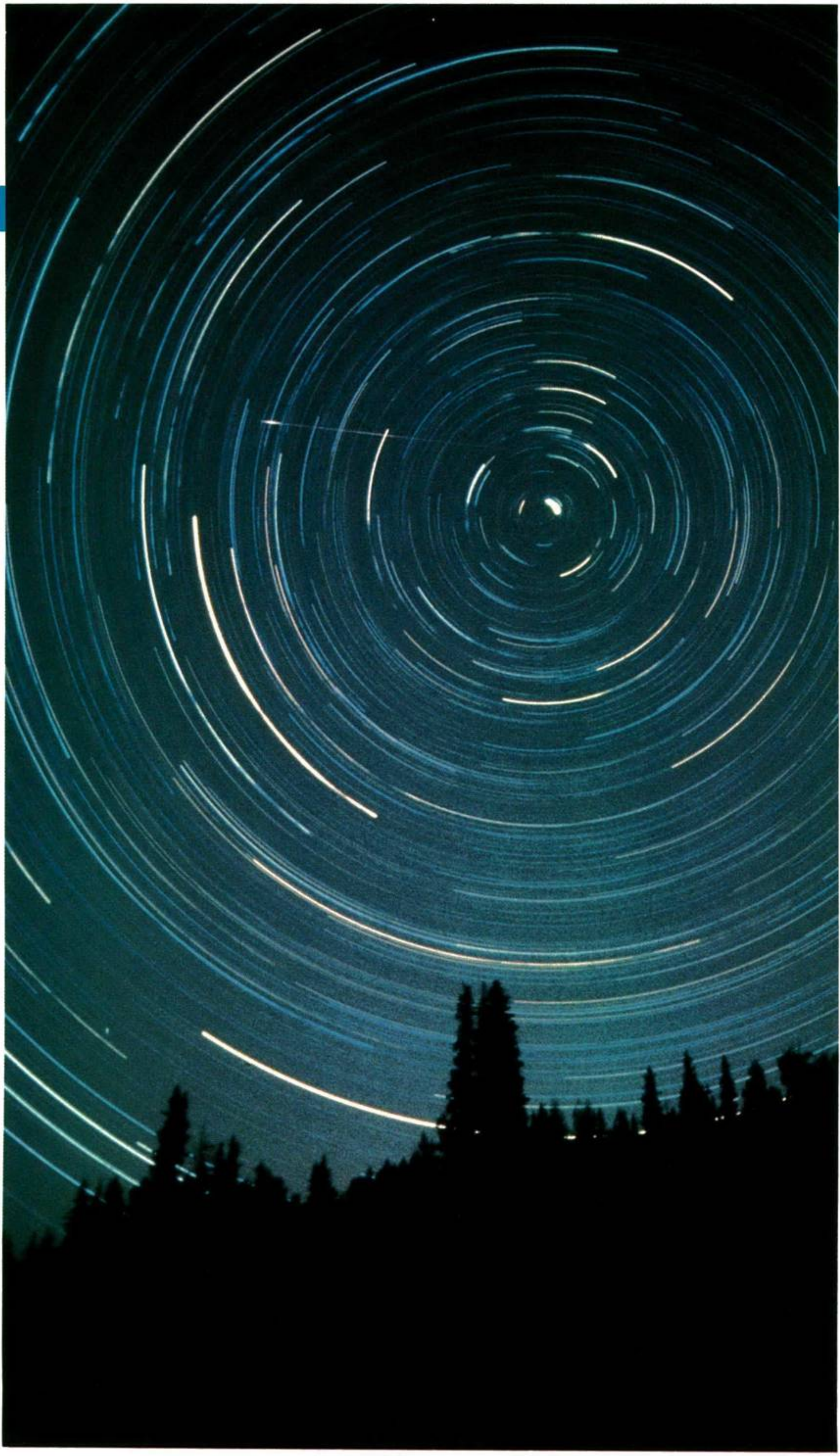
ON THE COVER: We haven't seen a view of Saturn as sharp and detailed as this since *Voyager 2*'s visit in 1981. This image was taken by the *Hubble Space Telescope*'s Wide Field/Planetary Camera during its summer check-out phase. It will take the cameras of the planned *Cassini* probe to reveal Saturn better than *Hubble* has. For details of the *Cassini* mission, see page 42. NASA photo.



A LOVELY PERSEID METEOR streaks away from the pole in this photo by Dale Lightfoot. December features the Geminids, the year's best meteor shower. For full details, see page 72.

ASTRONOMY®

December 1990

Vol.18, No. 12

28 Tycho Brahe Lights Up the Universe

The man with the silver nose had eagle eyes. Tycho revolutionized our view of the universe, all without the aid of a telescope. By William J. McPeak.

36 Built to Last

Building space probes that can last 20 years in space is not an easy task. By John Williams.

42 Voyages to the Worlds of Ice

CRAF and *Cassini* promise to be the *Voyagers* of the new century. By Robert Nichols.

48 Magellan's First Views of Venus

The first images from the *Magellan* Venus Orbiter have given us a teasing sample of incredible pictures yet to come. By Robert Burnham.

52 ASTRONOMY Sky Almanac

62 How to Find a Lunar Volcano

Discover where to look for the most elusive lunar feature — volcanoes. By Michael T. Kitt.

67 ASTRONOMY Tests Two CCD Cameras

The ST-4 and Lynxx cameras face off in a chip-to-chip comparison test. By Richard Berry.

72 Observe the Geminids — Before They Disappear

Put on a parka, brew a flask of coffee, and head outside for the best meteor shower of the year. By Philip M. Bagnall.

78 Challenging Winter Nebulae

They're big, they're faint, they're subtle — they're wispy bits of starstuff. They're the winter sky's most challenging nebulae. By Phil Harrington.

Departments

6 Behind the Scenes

6 Letters

13 Viewpoints
Ballad of the Teenage Astronomer

22 AstroNews
HST Goes to Work

24 Space News
The Fight for *CRAF* and *Cassini*

26 Amateur News
Observers Gather on Mount Kobau

83 Reader Reports

90 New Astronomy Products

92 Product Reviews
A Useful Binocular Mount

96 Astronomy Books

98 Meetings and Events

100 Readings and Resources

100 Credits

102 Advertiser Index

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Behind the Scenes

THE FOUNDATION OF SUCCESS

Who would have suspected an eccentric nobleman with a penchant for dueling would start a revolution in astronomy? But he did. In the year 1572, a brilliant supernova in Cassiopeia caught the eye of Tycho Brahe. Tycho's subsequent lifelong passion for precise measurements of the places of the planets and stars in the heavens laid the foundation of modern astronomy.

In modern terms, Tycho was an observer. Not theoretically inclined, the young man built an observatory, constructed the best instruments he could, and proceeded to bang out tens of thousands of measurements. The greats who came later — Kepler and Newton — based their laws and constructed their theories on Tycho's solid base of observation. The system they discovered in Tycho's data — with planets orbiting a central Sun according to the laws of mathematics — is central to our modern view of the universe. Our story on Tycho begins on page 28.

Today we humans are exploring that realm Tycho helped open. Our robot spacecraft have pierced the crystal spheres and flown to the planets along orbits that Tycho's measurements uncovered. Although space is not a benign environment, the craft we launch have survived remarkably well. It won't be luck that keeps *Galileo* going — it was built to last. Our story about the little spacecraft that could begins on page 36.

Magellan is now in orbit about Venus and sending back a mass of data every day. Like a modern Tycho, *Magellan* is an observer. From that data, Earth-bound astronomers and geophysicists will build a basis for understanding the geology of the cloud-wrapped world. The pictures that have come back so far show a highly volcanic planet similar to Earth in intriguing ways, yet radically different. Our report on *Magellan's* mission begins on page 48.

Even as I write, astronomers are preparing for the future exploration of the solar system. Yet these preparations, as you may know, may be in vain. The crisis in the middle East, America's burgeoning national debt, and the sour mood from the *Hubble* debacle may conspire to cancel the *Comet Rendezvous and Asteroid Flyby* mission (*CRAF*) and the *Cassini* mission. These missions, in the far more complex and technical age we live in, continue the tradition that Tycho Brahe set nearly four hundred years ago. Our story on the paths *CRAF* and *Cassini* will blaze — if America choses to fly them — begins on page 42.

Sincerely,

Richard Berry

Richard Berry
Editor-in-Chief

ASTRONOMY

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Letters

We Forgive You, NASA...

When the world's great cathedrals were first built in the late eleventh century, they towered over the comparatively humble dwellings of even the wealthy. Those who built them had no knowledge of how to calculate the forces generated by such masses of stone, and, not surprisingly, bits of them fell off. They were repaired, however, often in more beautiful architectural styles than the originals.

Any truly ambitious undertaking, the Romanesque cathedrals or the *Hubble Space Telescope*, will be subject to accidental error at the outset. — *Geoffrey M. Keyte, Much Cowarne, Hereford, England*

Your magazine seems to be going light on NASA over its current problems. Published reports show that NASA and Perkin-Elmer ignored chief scientist Roderic M. Scott's warnings about problems with the *Hubble Space Telescope*. Other reports suggest that NASA ignored engineer Bill McGinnis' warnings about hydrogen leaks on the space shuttles. NASA seems to be locked into a permanent state of denial to avoid appearing like complete fools. Are you also in a state of denial? — *William H. Warrick III, Gainesville, Florida*

$1,000 Worth of Article

Your articles on $1,000 worth of eyepieces were well done ("Product Reviews," August and October, 1990). In particular, your comparison of eyepiece apparent fields by viewing through the eyepieces to see the field stop is commendable.

Many observers repeat the mistake of measuring the true field of a telescope using the "star-drift" method, and simply multiply the true field by the magnification to get the "apparent field." This is an approximation at best. Short of ray-tracing the optical design, looking through eyepieces to gauge apparent fields as well as aberration effects is the best method of evaluation.

I'd like to caution your readers, however, about your statement elsewhere in the October issue "you shouldn't buy a fast f/4 or f/5 telescope for observing from light-polluted urban or suburban skies."

This is quite misleading, since the same aperture scope at the same magnification delivers the same exit pupil, regardless of the focal ratio. Indeed, no *binocular manufacturer* ever talks about his or her f/3 or f/4 objective.

Your pros and cons on telescope

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When we introduced our Plössls 10 years ago, they started an eyepiece revolution. Richard Berry, editor of Astronomy magazine said in his glowing review - "sharpest I've ever used!" Tele Vue Plössls are all designed by Al Nagler, and received U.S. patent #4,482,217 which recognizes the improvement in astigmatism correction (better edge sharpness). Further, they have the following features never before combined in a single eyepiece; a wide 50° apparent field, parfocalization, high-index glasses, multi-coating, barrels threaded for filters, anti-reflection metal threading, and blackened lens edges for maximized contrast.

Over the past few years many companies have jumped on the "Plössl" bandwagon. Some sell "house-brands," while others have added an element to impress you, calling the eyepieces Plössls even though the design resembles an Erfle. Ten years ago, Tele Vue Plössls were designed for sheer performance, not maximum marketing advantage.

Sure, imitators and "house-brands" come close to Tele Vue, but they haven't quite made the grade yet. Tele Vue Plössls still deliver the sharpest fields edge to edge with the least amount of lateral color. Plus, we now include a rubber eyeguard with every model, and maintain our 100% full field inspection process at f/4. Consistency is so good, you'll never have a problem buying pairs for binocular instruments.

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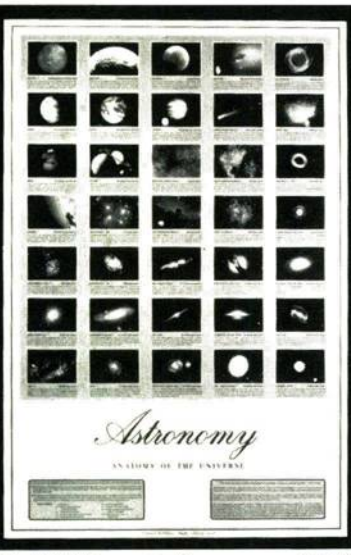

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types are generally well thought out, so I was disappointed that your discussion of telescope types listed the principal defect of refractors as chromatic aberration, without the qualifying remark that apochromats greatly reduce this effect. — *Al Nagler, President, TeleVue Optics, Pearl River, New York*

Aw, Not Again!

The letter in your September 1990 issue about renaming the Dumbbell Nebula struck a chord with me (and I bet with many readers).

As a former planetarium lecturer, I remember having to talk to many groups of school children. When I told them about the Dumbbell Nebula, it invariably produced bursts of giggles and whispers. I then had to spend five minutes explaining why a nebula that looks nothing like a real dumbbell is called the Dumbbell Nebula.

Why not ask your readers to submit proposals for a new name for M27 and then pick the best? My suggestion would be the Hourglass Nebula. — *Ed Mullen, Monterey Park, California*

Pinpointing the Origin of Comets

In his article "Where do Comets Come From?" (September 1990), Damond Benningfield mentioned the possible existence of a belt of comets just beyond the orbit of Neptune. Readers may be interested in work done by S. E. Hamid of the Smithsonian Astrophysical Observatory on this subject. His study published in 1969 attempted to determine whether or not a belt might explain residuals in the orbits of Uranus and Neptune. Hamid provided limits to the mass of such a belt for varying distances from the Sun.

The existence of such a comet belt might also affect Pluto. According to Gerard Kuiper's protoplanet hypothesis, such a belt might represent leftover condensation from the solar nebula. One estimate places such a belt 40 astronomical units from the Sun. If we assumed this belt exists near the ecliptic plane, Pluto would pass through the belt during each revolution about the Sun. If this were so Pluto might disrupt some of the comets, knocking them in toward the Sun. It might also produce craters on the surface of Pluto. — *Harald Schenk, Sheboygan, Wisconsin*

How to Beat Aperture Fever

The thing that makes aperture fever so dangerous is that it is contagious. When one amateur astronomer reaches critical mass there's another one who is critical mass once removed. So there's a constant demand for your present telescope, helping you to rationalize buying a bigger one at any given time.

Here's how to beat aperture fever. When an amateur astronomer you know buys a new telescope, tell him or her that if they ever want to get rid of it, to let you know. They'll automatically start thinking about larger telescopes and you'll be set up well for your next step up. — *C. Ed Boutwell, Columbiana, Alabama*

Customers: Pollute (and Spend) Away!

I am nearly in a state of shock from a package of fliers I received from our local utilities company. Even in an era of runaway light pollution the present material seems unbelievably revolting. I live in Hoboken, New Jersey, and our Public Service Electric & Gas Company's latest advertising campaign includes pitches for a "National Night Out." The campaign suggests that neighborhood residents everywhere sit outside, turn on their lights, and "celebrate" their stand against crime. The brochures suggest customers "turn on their porch lights" and stop crime by "pushing back darkness." Of course studies show that the relationship between night lighting and crime is almost nonexistent.

Another pamphlet encourages homeowners to spruce up their houses by "lightscaping." By adding exterior lights residents can "extend the day for family fun around the pool, porch, and patio, shedding a magical glow on your landscaping and illuminating walkways for safety." An introductory booklet, ironically illustrated with stars on the cover, is available to PSE&GC customers everywhere.

Aside from being an uninventive ploy to drain as many dollars from as many people as possible and to waste as much energy as possible, this is a brazen attempt to introduce scads more light to the night sky. If greedy utilities like PSE&GC have their way, forget about the light pollution warnings for the next century — they'll destroy skies for astronomy by next year. — *John Rounds, Hoboken, New Jersey*

Astrology Lives On

I've been reading over the flood of letters regarding astronomy *vs.* astrology in your letters column over the past few months. I can't understand why common sense doesn't apply to many modern people. At the time when Comet Austin was bright and visible, I proposed an article on the comet for the lo-

Photo by Tom Orzechowski

AN OWNER'S VIEW: Genesis™

DEAR MR. NAGLER,

Several years ago, I purchased a 10" Schmidt-Cassegrain telescope. On this new instrument, I carefully compared the performance of the most respected brands of eyepieces before concluding that the **Tele Vue** Plössls were giving me the best views. Along with 4 of your Plössls (55, 26, 17 and 13mm) and your 2.5x Barlow, I bought a Giant Off-Axis Guider, which I frequently use as a telecompressor. Although I have always been pleased with your eyepieces, there are limits to just how much a long-focal-length telescope can be telecompressed! ■

For over three years, I have wanted a second instrument for rich-field observing and photographing. Although your **Renaissance** is most impressive, it just wasn't quite the instrument I wanted and the **Oracle** was a bit too small. Then came **Genesis.** Knowing what a stickler you are for details in both design and production, plus my total satisfaction with your eyepieces; sight unseen, I bought a **Genesis** based solely on those facts and your ads in the magazines. ■

I took delivery of my **Genesis** at the Texas Astronomical Society's meeting on 7/22/88. Even with all the light pollution in that North Dallas parking lot, my new **Tele Vue** 32mm Wide Field eyepiece, at less than 16x, clearly resolved Saturn's rings as separate from the disc. When a friend asked to try his 12 mm Nagler-II with his 3x Barlow, I knew I had bought a "winner." The Cassini Division was as sharply defined as I have ever seen it plus the surface and ring detail was second only to a view I once saw under a Texas Star Party's dark skies through a nearly $20,000, 10.7" f/15 Maksutov! ■

The reason for this letter is simple. I have now had my first opportunity to take my new **Genesis** out to the T.A.S.'s dark-sky observing site (100 miles north of Dallas). In short order, the **Genesis** had attracted a group of experienced observers (most holding full Messier Certificates) away from their larger telescopes. Simply, **Genesis** stole the show! Except for an occasional comparison view, my 10" Schmidt-Cassegrain sat idle because I was seeing far greater clarity and detail with my new **Genesis.** Although I had with me a full set of filters (Deep Sky, U.H.C., O-III and H-β), none were ever used. ■

While I had anticipated a gorgeously resplendent Double Cluster, it was truly more dazzling than I expected. But, some real surprises lay ahead. Take M-33 in Triangulum: 4" just isn't enough aperture for such a diffuse spiral, right? WRONG! With the 32mm Wide Field, I was seeing tremendous detail in a galaxy over 1/3 the width of the field. I could write paragraphs describing a California Nebula covering half the field plus all the glorious sights through Sagittarius and Scorpius like the Lagoon, Trifid and M-21 all in the same field; or, four gleaming globulars, M-22 & 28 with NGC-6638 & 6642. ■

While the Great Andromeda Galaxy (M-31) spread across more than 2/3 of the field, we were all alternating time at the eyepiece, trying to see who could count the most dust lanes. It was more beautiful than even the photographs from the leading observatories. I have never seen M-110 appear as large relative to M-31. One observer even held his hand in front of the eyepiece and suggested that we try observing a projected image! While that may have been beyond even **Genesis'** capability, it does prove we were looking at no dim M-31. There was a debate over which eyepiece provided the better view: the 13mm Nagler's greater contrast and detail or the 32mm Wide Field's greater coverage. Each outperformed the other in its own way and both provided splendid views. ■

All night, comments from seasoned observers included a thesaurus-full of one word expletives of praise, wonder and astonishment. While glued to the eyepiece, other comments included: "...but this is ONLY a 4-inch" to "Boy! You sure made no mistake in buying this one" and "Oh, No!... How am I ever going to make my wife see the need?". One observer even yelled to a friend across the field, "Get over here if you want to see what Rich Field is SUPPOSED to look like." Personally, I can hardly wait to start taking astrophotos with it. ■

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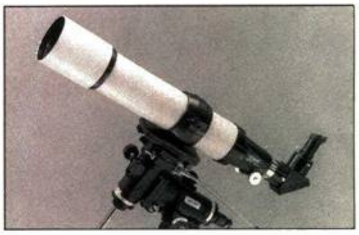

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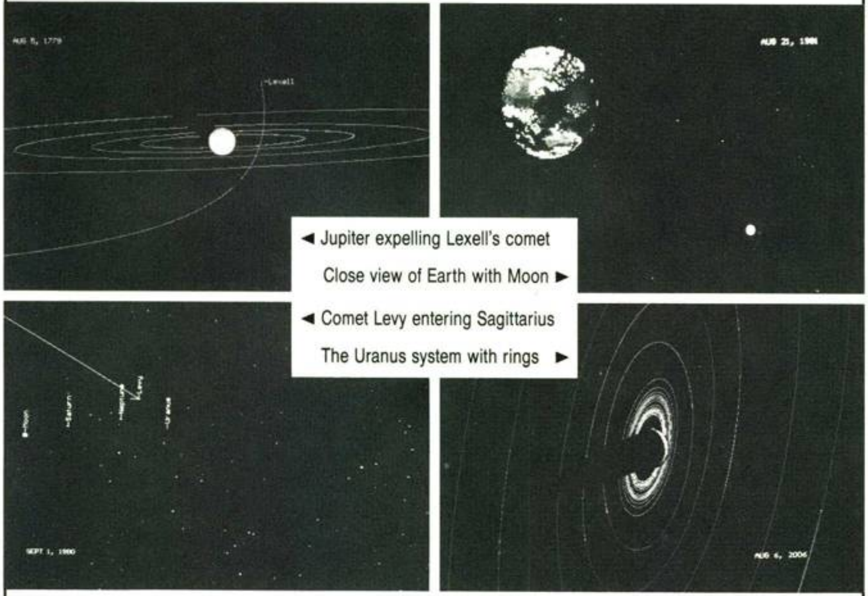
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cal newspaper. They rejected the idea, saying that it wouldn't be appealing to readers. Yet in the issues that followed the paper ran a series of twelve articles on each of the zodiacal signs, each article consisting of more than half a page! — *Bassel A. Reyahi, Tulkarm, West Bank, Israel*

Telescope Tips

I really liked "Ten Tips for Improving Your Telescope" by Alister Ling (August 1990). I own a 4.5-inch Newtonian and I think that amateur astronomers should push the observational limits of their telescopes before moving on to a larger size instrument.

I would have enjoyed seeing the article describe how to properly offset the star diagonal in a Newtonian to better intercept the light cone. In fast Newtonians, this would improve performance greatly and would not require the more expensive and cumbersome reduction of the size of the secondary and subsequent lowering of the eyepiece.

This is especially important when applied to the extremely fast optics used in many of today's reflectors. For an explanation of this procedure, readers should see *All about Telescopes* by Sam Brown (Edmund Scientific Co., Barrington, New Jersey, 1975). The best reason to do this procedure is that it requires a minimum of time and money. — *Alan Pasicznyk, Doylestown, Pennsylvania*

Things that Might Exist?

Gerrit L. Verschuur's article "Do Astronomers Believe in Things that Don't Exist?" (August 1990) strikes at an increasingly annoying theme in many research papers across the science and engineering literature. For me, the "cleverness" syndrome isn't as bothersome as it is to Verschuur.

Instead, I'm upset by the need to publish a large number of papers annually to bolster one's list of accomplishments. This leads to many fluffy and unimportant papers not just being submitted but published in many research journals. Don't scientists, who are supposed to be objective and impartial and honest, have any dose of integrity? — *Alex Pathan, Sheffield, England* □

ASTRONOMY welcomes comments, suggestions, and additional information on articles and astronomy in general. Send your letters to: ASTRONOMY Letters, P.O. Box 1612, Waukesha, WI 53187. Letters may be edited for length or clarity.

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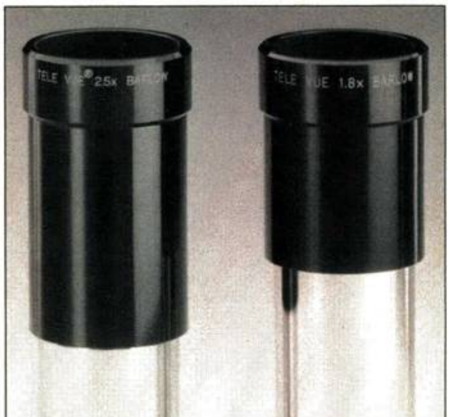

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Viewpoints

BALLAD OF THE TEENAGE ASTRONOMER

by Thomas Pannuti
(who is one)

Friday afternoon during school hours. I fidget anxiously with my pen while I wrestle with calculus and watch the clock at the same time. Suddenly, the final bell.

Along with the rest of my class, I bound out into the hallway while the teacher is announcing the weekend's homework. I take the books I need from my locker, head out to my car, and am soon on my way home. Upon arriving, I change my clothes for the wild night I have planned this evening — and begin poring over star charts of Orion!

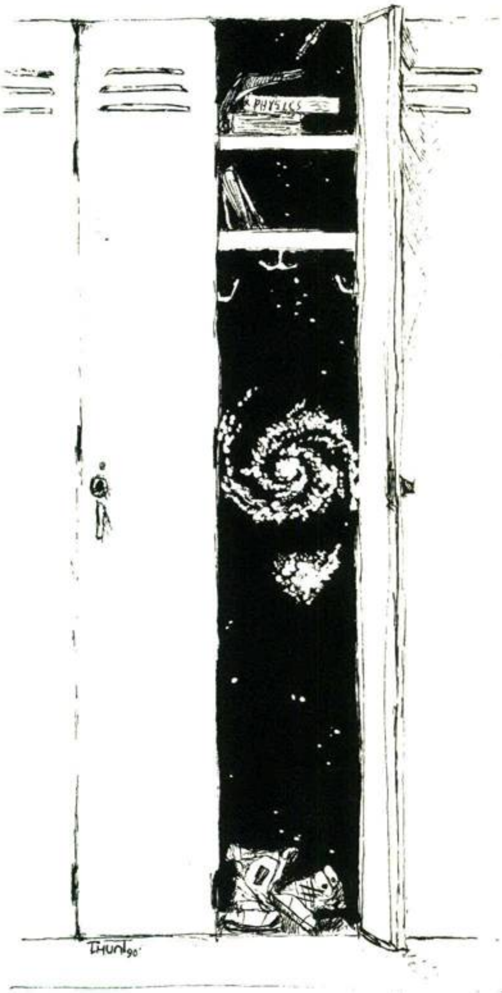
Most amateurs who have been interested in astronomy since their teen years can probably recall spending Friday afternoons somewhat as I did — and probably don't consider it at all unusual. But for the vast majority of nonastronomical persons, especially teenagers, the preceding may have seemed absolutely ludicrous. Who in their right mind would spend (waste?) a perfectly good Friday night behind a telescope instead of out socializing somewhere? I mean, get real!

To judge by the image of teenagers in the media, it would appear that the phrase "intelligent teenager" is a contradiction in terms. Teenage males are tireless pursuers of teenage females, while the latter are brainless creatures solely concerned with hair, makeup, fashion, and cute teenage males. Onto this scene enters the teenager who is more than casually interested in the skies above.

What's it like to be a teenager and an astronomer? It is an existence of apparent contradictions; for example, in my own room you will find two posters: one is of M42, the Great Nebula in Orion, and the other is of the rock group U2.

Another feature of the astronomical teenager's odd existence is the choice of music to listen to while observing. While almost every adult astronomer I know prefers classical music for stargazing, I prefer mostly hard rock and heavy metal. For every part of the sky I have my own soundtrack: Aerosmith for the Orion region, Guns N' Roses for Scorpius and Sagittarius, Heart for Hercules and Ophiuchus, U2 for the Summer Triangle, and so on. Even in my locker at school, you'll find a New York Giants pennant, a Guns N' Roses CD cover, and a bumper sticker from the American Association of Variable Star Observers, asking "Did You See SS Cygni Last Night?" (This last generates a great deal of curiosity from passers-by).

Another quirk in the life of the teenage astronomer is a certain kind of loneliness. By this I mean that I have never seen another teenager with the same passion for astronomy that I have. My friends are not oblivious to astronomy; some are fascinated by black holes and were intrigued by the lunar eclipse in August 1989. But I have never met another teenager who is as curious about astronomy as I am and who knows as much about the science as I do. This is possibly the most discouraging part of being a teenager and amateur astronomer — even more than the necessity of



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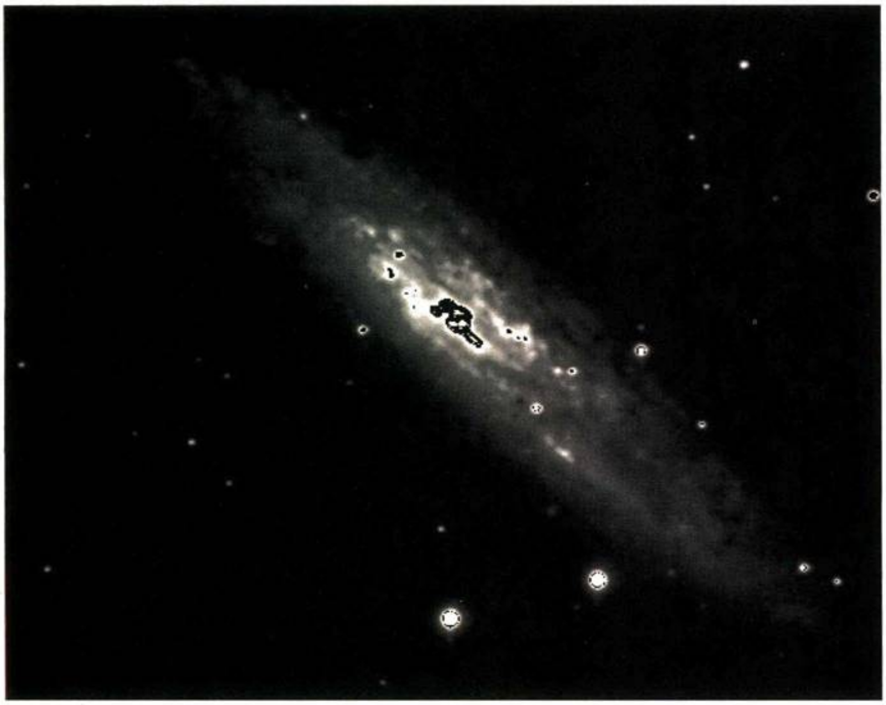

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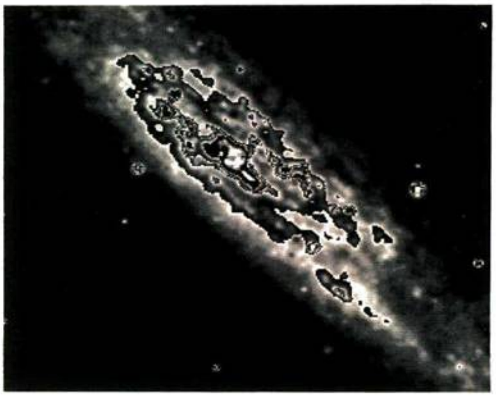

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getting up for school, which limits your all-night "runs" to Friday and Saturday nights.

But all in all, if I were to do it all over again, I would still get involved with astronomy. Sure, it has its quirks, its ups, its downs, its gray areas. But in the three years I have actively studied the stars, I have had experiences I'll never forget. Such as the first time I found Saturn's rings, Jupiter's moons and cloud bands, craters on the Moon, and Charles Messier's wild bunch: M8, M13, M20, M31, and, most recently, M15.

I would like to leave you with two experiences in the life of this teenage astonomer. First is the lunar eclipse that occurred the summer before last. My own experience was one of frustrating cloud cover, apparently more the rule than the exception for eastern observers that evening. Needless to say, I was not a very happy person; at midnight I found myself watching Monty Python's Flying Circus. (Yeah, I committed the highest crime of eclipse watching — I gave up.) But when I happened to look outside and found the skies suddenly clear with a 70-percent-eclipsed Moon visible, I rushed outside with my Walkman and to the tune of "Paradise City," "Sweet Child O' Mine," and "Nightrain" by Guns N' Roses, I caught the tail end of the show as the Moon emerged from Earth's shadow. Out there, I realized how much I really do love astronomy.

And finally, last November, after three years of unsuccessful coaxing, one of my friends finally convinced me to go to a dance our school was sponsoring. Was it worth it? Well... For $5 I had the opportunity to see some guys I know dance; plus I saw some very scary-looking girls. But once, when I stole a glance outside through the cafeteria window and saw some stars outside, I thought to myself: I don't belong in here. I belong out there.

WHEN I WAS YOUNG AND...

by Jeff Lageson

When I was younger I loved to look at the stars, read science fiction, and dream of going into outer space. It was one of those fascinations that most amateur astronomers can probably understand.

But I basically hated science.

In elementary school it was one of the few subjects I avoided. In fifth grade I wrote a short book about an alien invasion for a young author's con-

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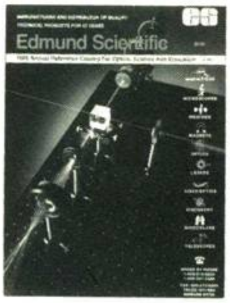

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ference. In it I made bold claims about ordinary rocks' being able to provide energy for faster-than-light spaceship drives and the Sun's being harnessed for the evil needs of aliens on their home planet. Well! Science then told me that faster-than-light flight was impossible, habitable environments on other planets were unlikely, and energy had to obey certain rules that made my fantasies look pretty foolish.

So I took out my resentment on Einstein and physics. I went on reading about astronomy, the planets, and space exploration because they were still attractive. But I kept to the fun stuff like Saturn's rings, photos of galaxies and nebulae, and manned space exploration. I avoided the serious, real part of astronomy because I felt it had killed the beauty of the stars.

Now I find I'm trying to deal with the fact that I've been wrong about science. Over the past couple of years I've begun reading popularizations of science that have been best sellers. Books by Carl Sagan and Stephen Hawking, for example, in which I've read about relativistic travel and speculations on extraterrestrial intelligence. I've also started to get interested in the details in the more technically oriented stories in science magazines. I took a basic astronomy class in college, where one of my roommates even got me reading Einstein himself on relativity theory. Admittedly, I eased myself into it. Let's face it, Sagan reads a lot better than a textbook or lab manual.

What has this done for me? Well, I've found out that understanding the basics of scientific theories — theories that blow away most of the science fiction that I still love and read — have actually enhanced the beauty of astronomy for me. Sure, I'm not well versed in the finer points of physics and what-not, but that's beside the point. What matters is that the science that scared me off now has me wholeheartedly interested in it. I'm considering taking some classes in the sciences I avoided.

I also see what the problem was when I was younger.

Instead of reading material that furthered my interest in and knowledge of astronomy in a suitable way, I plowed right into the big stuff and it confused the daylights out of me. This sort of confusion can deal a heavy blow to your pride — and I just didn't like that when I was in elementary school and junior high. Moreover, the feeling carried over into high school and college. In college (where I majored in history as an undergraduate and took most science courses grudgingly), I could handle the confusion a little better. Besides I had a roommate to give me a better explanation about the speed of light and other things.

That would have helped when I was younger, too.

There are bound to be a lot of kids out there who have the same interests — and the same confusion — that I did. A simple physics and astronomy class in elementary school or junior high might have solved the problem for me. With terminology geared to the right level, the questions I had could have been answered and I might have understood the basics a whole lot better. Who knows? I might have stuck with science.

And it isn't just astronomy, either. You notice the same thing if you look around at all the sciences. Kids like science all right, but there just isn't enough of it presented in ways that catch their interest. Sure, you get some fundamentals in chemistry classes about acids and bases and so on. But the only science I knew when I graduated from high school was chemistry. Okay, I also knew what frogs and worms looked like when cut open, but I knew little at all about what really makes the world around us tick.

The United States has entered a period when the entire educational system is being scrutinized by the public, and it's obvious that the curriculum is overdue for a major overhaul. Part of that overhaul needs to include the sciences of physics and astronomy. Basic experiments that kids can understand and learn from are fun and easy and would be cheap. (How much do photocopies of sky charts cost?) Activities with star charts, for instance, can teach a lot about the movements of the stars, planets, the Moon, and Earth while keeping it fun.

This sort of thing is precisely what's needed in our educational system. The natural curiosity of kids needs to be encouraged so that they aren't scared of science. Unfortunately that curiosity is being largely wasted. And collectively we are going to be in big trouble in the early stages of the 21st century if something isn't done now.

However, science teaching (or at least its content) has become a captive to politics, held hostage by various pressure groups. There will always be people who are afraid that if their children learn *some basic concepts of the universe* they will draw away from various faiths. That cannot be helped. There *will* be

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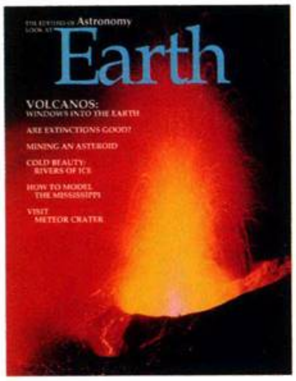
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fierce arguments over science teaching, unavoidably. To its credit, the scientific community seems to be trying to increase the role of science in the curriculum — and its quality. These efforts need to be backed strongly and more public attention needs to be focused on the issue.

Science doesn't bite; I know that now. Science can make the beauty of the stars and the world that much more beautiful. I wish I had learned that simple fact when I was younger, in an environment that nurtured my curiosity.

But that's past. What counts now is that tomorrow's students should have that chance too, and right now they're being cheated out of it.

NASA NEEDS CRAF/CASSINI

by Louis Friedman,
Executive Director of
The Planetary Society

Once again space science and exploration is bearing the brunt of problems in the space program. Funding for both the *Cassini* mission to Saturn and the *Comet Rendezvous/Asteroid Flyby (CRAF)* is in jeopardy. The funding is threatened by demands imposed by shuttle delays, the ever-increasing space station drain on the NASA budget, and the relatively low priority that scientific missions have within NASA.

In 1989, when Congress approved a new start for the *CRAF/Cassini* missions, it looked like the United States would resume its exploration of the solar system that in the past had brought universal acclaim. The *Mariner, Voyager, Viking,* and *Galileo* missions approved in the 1970s would now be succeeded by two new spacecraft bound for the outer solar system. The joint *CRAF/Cassini* probes have been designed around a common spacecraft and a common scientific goal — to explore some of the most primitive worlds in the solar system.

Cassini is an international mission to Saturn, scheduled for launch in 1996 aboard a Titan IV Centaur rocket. After flying past an asteroid, *Cassini* will enter Saturn orbit in 2002. The sophisticated scientific payload will explore in detail Saturn's rings, moons, atmosphere, and magnetic field — each a suitable subject of study in its own right. But for many, the crowning achievement of this mission will be the release of the European Space Agency's *Huygens* probe

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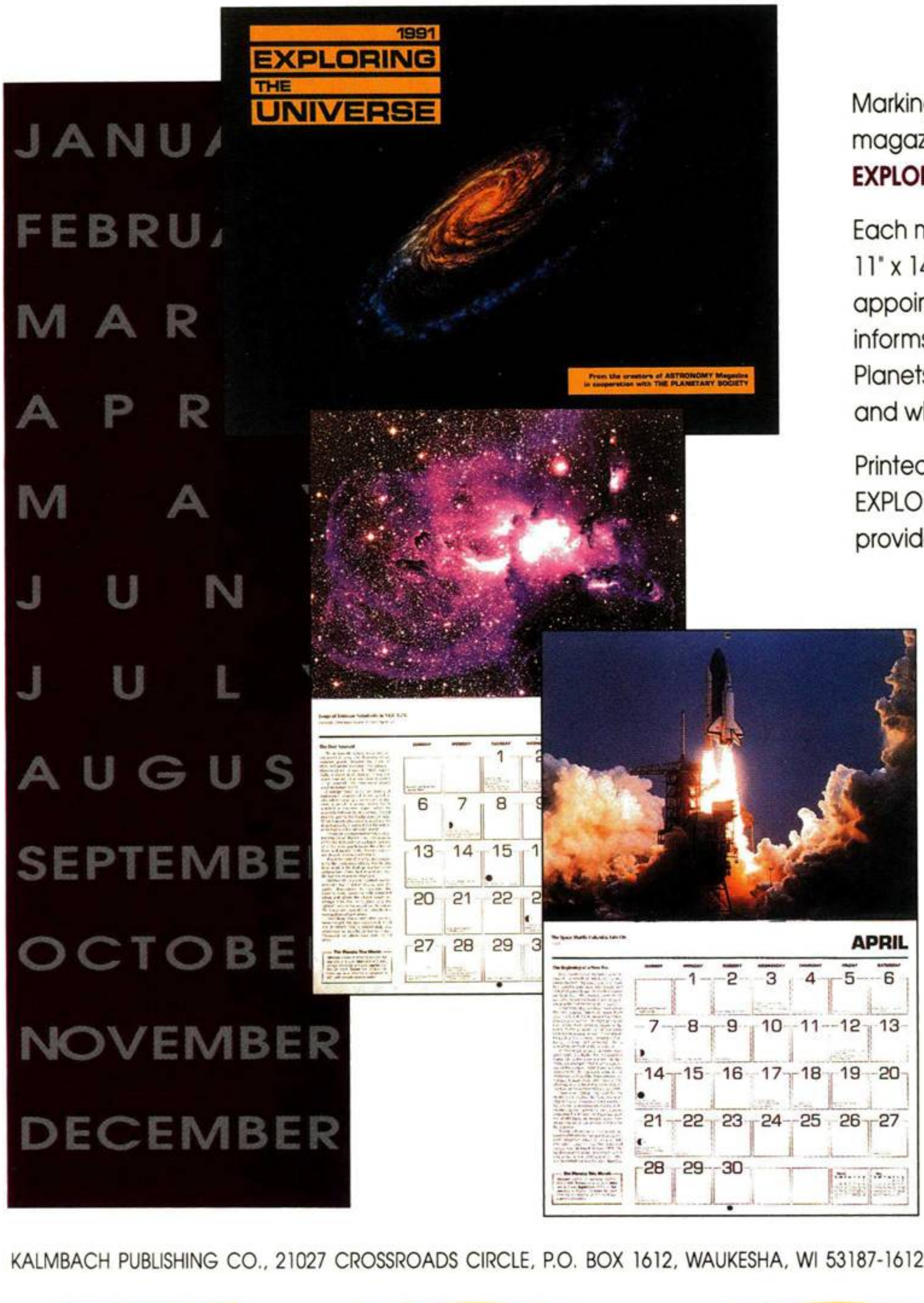
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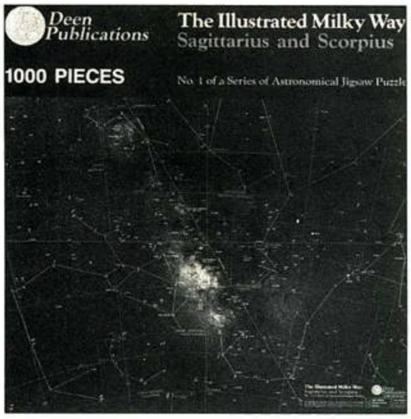
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into the atmosphere of the Saturnian moon Titan. Titan is believed to have an atmosphere rich in hydrocarbons and may have lakes of liquid ethane with methane rains. Such an organic-rich world has much to teach us about the processes that led to the evolution of life here on Earth.

The companion *CRAF* mission is scheduled for launch in 1995. It will fly past an asteroid and encounter Comet Kopff in the year 2000 near its most distant point from the Sun. It will then fly with Kopff for three years as the comet approaches the Sun. Detailed images and scientific data will be obtained during this period. Also planned is an unprecedented effort to send an instrumented penetration probe directly into the comet's nucleus, where it will analyze the composition of what are believed to be the most primitive bodies in the solar system. Comets and asteroids provide us an opportunity to "look back in time" to learn about the origin of our solar system.

When the missions were approved, a budget cap was placed on them to prevent cost overruns. The project managers at NASA and JPL said they could do the job if the program remains free from delays that would cause cost overruns. Now if the budget is cut that schedule is in jeopardy, and the *CRAF* portion of the two-craft mission might well be canceled altogether.

Canceling *CRAF* and delaying *Cassini* would increase overall costs, waste already expended money, and reduce the scientific return from planetary exploration. This would be a body blow to a program that has served the United States and the world so well. And it will retard the United States' progress as an exploring nation.

The Planetary Society, along with a host of scientific and technical organizations, has urged full funding for *CRAF/Cassini*. We believe the priorities that assign low value to good scientific missions are wrong-headed and ultimately foolish. We hope the day will come when the value of planetary science is not annually challenged in the setting of national budgets and the balancing of our space priorities.

In support of *CRAF/Cassini*, the Society has written to every member of Congress (contacting many of them individually) and urged its members to write Congress. We ask ASTRONOMY readers to do the same. And we should all urge NASA to increase the priority of space science and exploration in the space program. ☐

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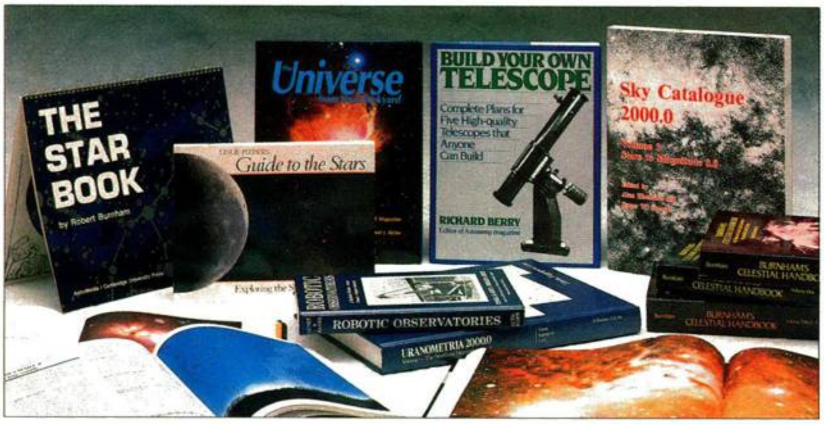

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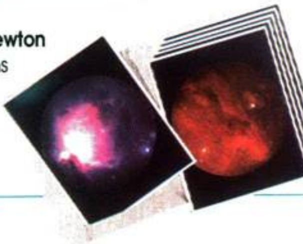

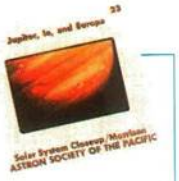

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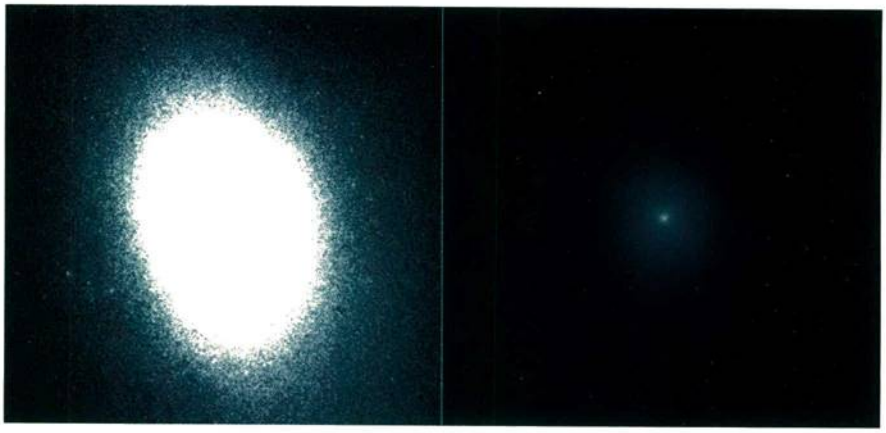
HST GOES TO WORK

Despite a primary mirror flawed by spherical aberration, *Hubble* is revealing details in celestial objects never before seen. In images taken late this summer to assess the science performance of *HST*, the spacecraft's Wide-Field/Planetary Camera found a surprisingly high density of stars in a normal galaxy, and the Faint Object Camera revealed a ring of material surrounding supernova 1987A.

The elliptical galaxy NGC 7457 was chosen as an early target for *HST* precisely because it appears to be a normal, quiescent galaxy. But astronomers found it to have an exceptionally bright and compact nucleus embedded in the diffuse glow from the rest of the galaxy.

The new image shows that stars in the nucleus of NGC 7457 are concentrated at least 30,000 times more densely than they are in the Sun's neighborhood of the Milky Way. This extraordinary stellar density is some 400 times greater than previous estimates of NGC 7457 based on observations made from Earth.

Astronomers are encouraged because it shows the capabilities of *HST*. "The images of NGC 7457 show emphatically that research on the nuclei of galaxies can still be done," says Tod Lauer of the WF/PC imaging team. "We've never been able to study any galaxy outside our Local Group at this resolution before." The centers of galaxies are of particular interest to astronomers because they appear to be at the heart of the violent processes that cause quasars, Seyfert galaxies, and cosmic jets.

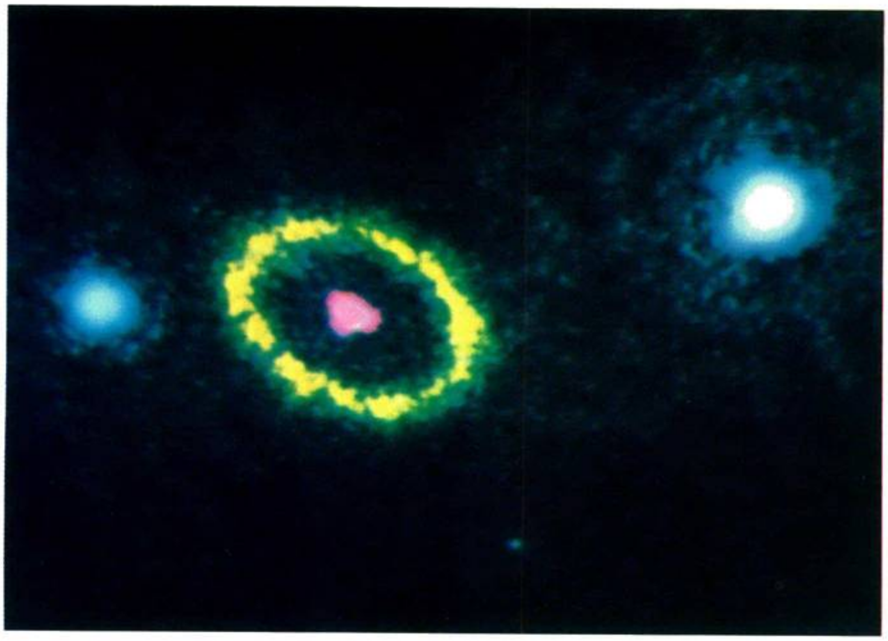


STARS CROWD TOGETHER at the core of NGC 7457. A high-contrast HST image of the central portion of the galaxy shows a smoothly increasing population density (left). Once the contrast is adjusted, however, the image reveals a surprisingly high density of stars concentrated at the galaxy's core (right). NASA image.

The European Space Agency's Faint Object Camera photographed the ring of material around supernova 1987A to a resolution of 0.1 arcsecond. The image was made in the yellow light of doubly ionized oxygen; the blue and red were added later to reflect the object's true color. The image shown here has not been computer reconstructed, so it gives a good idea of the raw information coming down from *Hubble*.

The ring is a relic of the supernova's progenitor star. While that star was a red supergiant (about 10,000 years before the explosion), it ejected much of its envelope in a gentle stellar wind. But when the progenitor star later evolved into a blue supergiant, the stellar wind picked up speed and swept up the diffuse gas, compressing it into a thin, high-density shell. Within a few hours of the supernova explosion, a flood of ultraviolet radiation heated the ring to incandescence. Three and a half years later, the ring still glows at a temperature of more than 20,000 kelvins.

The ring is now about 1.3 light-years in diameter and still expanding slowly. But it will survive only a few more decades. The rapidly expanding ejecta from the supernova (shown in red on this image), which is moving at about one-tenth the speed of light, will soon overtake, engulf, and destroy the ring. A bright supernova remnant will re-



RING AROUND A SUPERNOVA is what remains of the outer layers of the red supergiant star that eventually exploded as supernova 1987A. The reddish glow at the center of the ring is the still glowing center of the explosion. The blue stars to the left and right of the ring are not associated with the supernova. NASA image.

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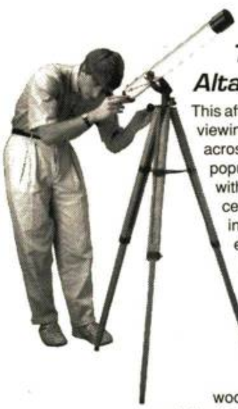

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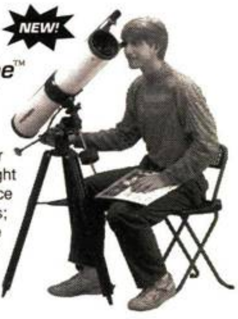

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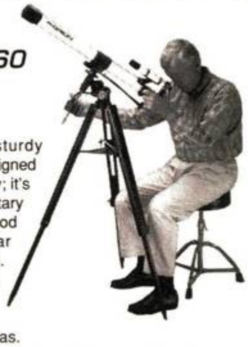

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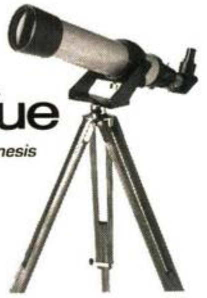

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Readers wishing to calibrate an observation — or set their watches — are reminded that the phone number of the U.S. Naval Observatory's master clock is (900) 410-TIME. Callers are billed 50¢ for the first minute (35¢ each minute thereafter) and calls are limited to 3 minutes. In the lower 48, the signal's delay in the phone system is kept to a constant 25 milliseconds.

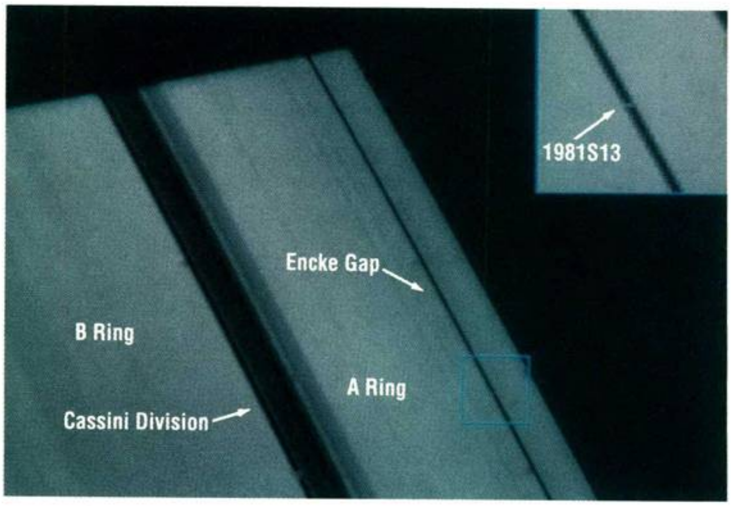
SATURN HAS A 'NEW' MOON — THANKS TO OLD DATA

Analysis of nine-year-old *Voyager 2* images of Saturn's rings has revealed the existence of a new moon orbiting in the Encke Gap and provisionally designated 1981S13. Planetary astronomer Mark Showalter of NASA's Ames Research Center in Mountain View, California, reported finding the satellite in 11 images taken by *Voyager 2* over a 48-hour period before closest approach in August 1981. Showalter and other ring researchers suspected the satellite was there because of transitory variations seen in the A ring near the Encke Gap. These disturbances were regular enough that calculations could provide an orbit and location for the suspected moon.

"We fed all the orbital data into the computer," says Showalter, "and then told it to pick out the likeliest *Voyager* images." The computer searched through over 30,000 images.

"The computer gave us, in the end, about 20 fairly promising images that had good enough resolution to be worth examining in detail. We found the moon in 11 of them." Showalter estimates that the new moon is about 20 kilometers in diameter and has a reflectivity of 40% to 70%, showing that its surface is mostly ice. This makes it similar to the ring particles and other moons in its vicinity.

NEW SATURNIAN MOON 1981S13 orbits in the Encke Gap, a narrow division in the outer part of Saturn's A ring. The object was found by searching *Voyager 2* images dating from 1981.



Space News

THE FIGHT FOR CRAF AND CASSINI

As ASTRONOMY goes to press, NASA's next expeditions to the outer solar system, the *Comet Rendezvous and Asteroid Flyby (CRAF)* probe and the *Cassini* mission to Saturn, are in danger of being cut from NASA's budget. Planetary scientists have been busy lobbying Congress and rounding up support from the astronomical community, including from amateur astronomers across the United States. Scientists are concerned that without the joint *CRAF/Cassini* program, NASA would have no new planetary missions for launch after the *Mars Observer* mission in 1992. (For a description of the *CRAF/Cassini* missions, see "Voyages to the Worlds of Ice" on page 42.)

However, even if funding is reaffirmed in the current round of budget debates, NASA faces a tight budget for the combined mission. When Congress originally approved the program in 1986, it was with the stipulation that the budget be fixed at $1.6 billion. This sounds like a generous budget, but the *CRAF/Cassini* missions require complex spacecraft to achieve the demanding scientific goals. That makes the spacecraft costly to build. (See "Built to Last" on page 48 for insights into what it takes to design space probes.)

The budget crunch for *CRAF/Cassini* arises in part because NASA had hoped for greater foreign participation in the program. Unfortunately, much of that participation didn't materialize. According to Howard Wright, *CRAF/Cassini* program manager at NASA headquarters, the European scientific community had already committed budgets to other projects. They just didn't have much funding left to take part in the *CRAF/Cassini* program.

A second reason for *CRAF/Cassini*'s money problems, Wright explained, is that the science instruments for the spacecraft are going to cost more than initially estimated. This problem has arisen before in many NASA programs. As the sensors and instruments are developed, engineers add more capabilities, which drive costs higher.

In an effort to keep the project within budget, NASA managers are "looking for ways to increase the commonality of the two spacecraft," said Ron Draper, deputy project manager at

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the Jet Propulsion Laboratory. If identical science instruments can be used on both craft, the overall budget can be reduced. Wright predicted that as many as five instruments can be made common for both spacecraft.

Some of the instruments may have to be removed from the payload, Draper explained. The initial list of instruments for any mission is really a straw-man payload that can be modified for any number of reasons, either economic or scientific. Canceling the *CRAF* half of the mission has also been suggested as an extreme method for solving the *CRAF/Cassini* crisis. The extra funds would ensure that *Cassini* would proceed without removing any science equipment.

Concerned readers who wish to express their support for *CRAF/Cassini* are being urged by planetary scientists to contact Barbara Mikulski and Jake Garn, respectively chairperson and ranking minority member of the Senate Subcommittee on HUD-Independent Agencies, 142 Dirksen Senate Office Building, Washington, DC 20510; (202) 224-7211.

As Jonathan Lunine, a planetary scientist at the University of Arizona's Lunar and Planetary Laboratory put it, "Congressional officers assume that if you cared and if it mattered, they would be hearing from you. Silence is interpreted as a lack of support, and in budget debates that leads to unfortunate outcomes." — *Robert G. Nichols.*

Amateur News

OBSERVERS GATHER ON MOUNT KOBAU

Each area of North America has its "mecca" star party for local amateur astronomers. For the Pacific Northwest, it's the Mount Kobau Star Party, held near Osoyoos in the Okanagan Valley of southern British Columbia, Canada.

Each year Kobau's legendary dark skies draw amateur astronomers from hundreds of miles away. Isolated from the rest of the world on Mount Kobau's 7,000-foot summit, deep-sky observers and astrophotographers hunt down challenge targets and get their best photos of the year. To maximize their dark sky opportunities, avid amateurs often arrive a week or more before the official starting date of the 4-day event.

However, weather conditions for 1990's edition of the star party from August 22 to 26 were enough to try the patience of even the most stoic observers. As the cosmic gremlins often have it, after two months of drought, record high temperatures, and clear skies in the area, a pattern of solid cloud cover locked in over southern British Columbia the week of the star party and refused to move. Luckily, holes in the clouds opened up on two nights, giving enough hours of viewing to partly quench the observers' collective thirst for dark skies.

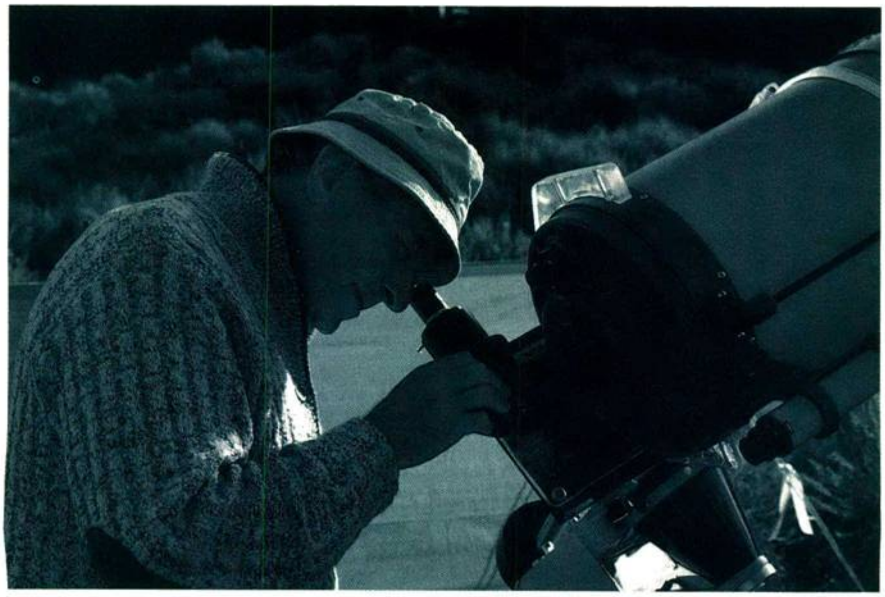
Compared to other star parties in North America, Kobau boasts of attracting the largest number of large aperture telescopes. The 14- to 20-inch scopes were out in force again this year, though many of them remained under rain tarps for most of the week. The winner for aperture this year, as in the past two years, was the 36-inch Dobsonian brought by Joan and John Casino of Olympia, Washington. Despite the fact that its mount was being refurbished with a new lightweight design and to accommodate computer-controlled stepper motors, the monster scope worked superbly. Throughout each night observers wandered down to the 36-inch and waited patiently for their look at old, familiar objects revealed as they had never seen them before. But the hit of both clear nights was a new target, Comet Levy, an easy naked-eye object drifting through Aquila. Through the 36-inch, the intense starlike nucleus of the comet appeared slightly tinged with red.

However, you didn't need the 36-inch to see colors in the sky at this year's Kobau. Nature cooperated by providing spectacular auroral displays both nights, though most Kobau devotees viewed the aurora as a nuisance, not a bonus.

During the day, many of the 160 or so in attendance were entertained by a first-class program of speakers: Lucien Kemble, a renowned deep-sky observer, astrophotographer Jack Newton, Tippy D'Auria, organizer of Florida's Winter Star Party, *Sky and Telescope's* Stephen O'Meara, and ASTRONOMY's Alan Dyer, gave talks on topics that ranged from the art of visual observing to the latest in CCD imaging.

This year's program was praised by many in attendance as the best yet in Kobau's seven-year history. Next year, Kobau organizers hope to top it with a return of the mountain's usual offering of clear, dark nights. The 1991 Mount Kobau Star Party will be held August 8 to 11, just prior to the peak of the Perseid meteor shower. □

TAKING ADVANTAGE OF BRIEF CLEAR SKIES Father Lucien Kemble, a frequent contributor to ASTRONOMY and *Deep Sky*, tracked down daytime planets at this year's Mount Kobau Star Party.



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NEW!

These new Multi-Coated Plössl eyepieces are incredibly low priced! Good quality optics for sharp, clear images. Precision four-element Plössl lens elements mounted in sturdy aluminum barrels. Available in 12mm, 18mm, or 25mm focal lengths, with 1.25" barrels. Buy all three for less than some single eyepieces!

12mm-#8596
18mm-#8597
25mm-#8598

$39.95 ea. (2.39)

Orion® MegaVista™ 1.25" Wide Angle Eyepieces

Incredible Fully Multi-Coated high-transmission 7-element eyepieces with integral rubber eyeguard and long eye-relief.

10.5mm- An incredible 67° field for outstanding planetary or deep space performance.

#8552 **$109** (2.79)

16.8mm-Outstanding high-contrast eyepiece with stunning 70° field ideal for deep space.

#8554 **$119** (2.79)

Orion® UltraZoom™ 7-21mm 1.25" Eyepiece

The finest zoom you can buy for your 1.25" telescope. An excellent choice for astronomy or terrestrial observing. 65°-35° field.

#8556 **$129** (2.79)

Orion® Explorer Series 1.25" Eyepieces

Remarkably affordable, Multi-Coated parfocal eyepieces with great performance. Each carefully selected series has been chosen to provide a sensible progression of magnifications. Threaded for filters. Internally blackened to prevent stray light reflections.

Kellner Eyepieces-
6mm #8536, 9mm #8538, 12mm #8540, 18mm #8508, 25mm #8510, 40mm #8512

$33.95 ea. (2.19)

Orthoscopic Eyepieces-5mm #8500, 7mm #8502, 9mm #8504, 12.5mm #8506, 18mm #8524, 25mm #8526

$46.95 ea. (2.19)

Orion® Explorer Series .965" Eyepieces

Get the most from your small telescope with these fine Multi-Coated eyepieces. Standard .965" barrels fit all Japanese standard small telescopes.

.965" Orthoscopic Eyepieces-
5mm #8580, 7mm #8581
9mm #8582, 12.5mm #8583

$37.95 ea. (2.19)

.965" Kellner Eyepieces
18mm #8584, 25mm #8585
.965" Achromatic Huygenian Eyepieces- 40mm #8586

$24.95 ea. (2.11)

77° Field UltraScan Wide-Angle Eyepieces

NEW!

Unlimited visibility is yours with up to 77 degrees of field to catch your eye. High quality optical materials and superb coatings, for the ultimate in contrast and resolution.

1.25" UltraScan Eyepieces
Five optical elements utilizing the latest high refractive-index optical glass materials achieve extremely wide fields with fewer elements than many competitive eyepieces, reducing weight and cost. Each lens surface is fully Multi-Coated, for the ultimate in contrast and elimination of stray reflections. Integral rubber eyeguards.

9mm-#8420 **$99** (2.79), ***12mm***-#8421 **$109** (2.79)

15mm-#8422 **$129** (2.79), ***19mm***-#8423 **$139** (2.79)

2" UltraScan Eyepieces
These incredible oculars provide breathtaking panoramic, bright views that will astonish you!

30mm 2" UltraScan Eyepiece - This 5-element, 77 degree field UltraScan eyepiece combines the widest possible apparent and true fields with a larger image scale than our 40mm.

#8424 **$199** (2.79)

40mm 2" UltraScan Eyepiece - Orion's brightest, widest true-field UltraScan eyepiece utilizes a sophisticated 7-element design, providing a 68 degree apparent field; the widest we could fit into the 2" diameter barrel.

#8425 **$179** (2.79)

Plössl Illuminated Reticle Eyepiece

Our new Plössl design offers unprecedented eye relief and observing comfort sure to please the most experienced astrophotographer. This eyepiece is the equivalent of a 6.25mm eyepiece when used with a 2x barlow. Battery-operated integral illuminator, fully adjustable brightness, double crossline reticle.

#8484 **$99** (2.79)

Zoom Orthoscopic Eyepiece

NEW!

This fully coated 1.25" eyepiece zooms instantly from 8.4mm to 21mm, with excellent image correction at all powers. Wide 50° field at 8.4mm.

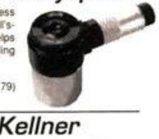
#8555 **$89.95** (2.79)

World's Finest Illuminated Reticle Eyepiece

6mm Orthoscopic design for required high-power guiding, plus unique X-Y adjustable reticle positioning for easy guide-star alignment. Wireless LED illuminator has adjustable brightness.

#8487 **$139** (2.79)

Orion® 9mm Orthoscopic Illuminated Reticle Eyepiece



9mm Orthoscopic eyepiece with wireless adjustable brightness illuminator. Bull's-eye within three concentric circles helps measure limits of acceptable guiding error.

#8488 **$119** (2.79)

Orion® 12mm Kellner Illuminated Reticle Eyepiece

12mm Kellner eyepiece with cable plugs into LX/3, LX/5 and Premier drive bases, and most drive correctors with illuminated reticle output for polar alignment and guiding.

#8482 **$69.95** (2.59)

100% Satisfaction

MONEY-BACK GUARANTEE

If you are not completely satisfied with your purchase from Orion, for any reason, just return it in new condition within 30 days after delivery for a full refund.

Orion® SkyGlow™ Enhanced Light Pollution Filters

Enhance your viewing of faint deep sky objects with the best broadband light pollution filter you can buy. Our SkyGlow absorbs frequencies emitted by city lights, allowing transmission of the rest of the visible spectrum, yielding dramatic results.

SkyGlow Broadband Filters-
For use in slight to moderately light polluted areas.

1.25" Broadband Filter-fits 1.25" eyepieces.

#5660 **$59.95** (2.59)

Schmidt-Cassegrain Broadband Filter- fits rear cell of Meade & Celestron SC scopes.

#5658 **$79.95** (2.59)

52mm Broadband Filter- fits all camera T-rings.

#5668 **$66.50** (2.59)

SkyGlow UltraBlock Filters- For severely light polluted areas.

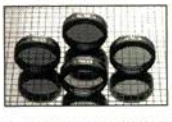
1.25" UltraBlock Filter- fits 1.25" eyepieces.

#5654 **$79.50** (2.59)

Schmidt-Cassegrain UltraBlock Filter- fits rear cell of Meade & Celestron SC scopes.

#5656 **$99.00** (2.59)

Orion® Color Filters for Eyepieces



Solar system observations are dramatically improved by Orion colored filters. For visual use, thread one into the barrel of any standard eyepiece. For planetary and lunar photography, Schmidt-Cassegrain owners can attach the filter to the eyepiece inside the tele-extender. Can also be threaded directly into a universal camera adapter.

Basic Set of 4 Filters .965"- Includes #80A Blue, #58 Green, #25 Red, #15 Yellow.

#5510 **$29.95** (2.19)

Basic Set of 4 Filters 1.25"- Includes #80A Blue, #58 Green, #25 Red, #15 Yellow.

#5514 **$39.95** (2.19)

Expansion Set of 4 Filters 1.25"- Includes #21 Orange, #47 Violet, #11 Yellow-Green, #82A Very Pale Blue.

#5516 **$39.95** (2.19)

Deluxe Set of 8 Filters 1.25"- Includes all the filters in our basic and expansion filter sets.

#5517 **$74.95** (2.79)

Individual 1.25" Filters- #80A Blue (#11040), #58 Green (#5540), #25 Red (#5536), #15 Yellow (#5532), #21 Orange (#5534), #47 Violet (#5538), #11 Light Yellow-Green (#5530), #82A Very Pale Blue (#5544)

$11.95 ea. (.99)

Moon Filters

Cuts 87% of the light from the Moon. Reduces glare by uniformly reducing light transmitted over the entire spectrum.

.965" #5664 **$14.95** (2.11)

1.25" #5662 **$14.95** (2.11)

Tele Vue Eyepieces

Improved with Built-in Eyeguards & Grip Rings

All Tele Vue eyepieces employ military-style features: blackened lens edges for maximum contrast and minimum scattered light built-in rubber eyeguards to protect your eyes from stray reflections, and rubber grip rings on the larger models for easy, slip-free handling.

Tele Vue Plössl

The 50° apparent field of Tele Vue Plössls is larger than the 40°-45° field of Orthoscopic eyepieces, so you see more of the sky at one time. Each 1.25" eyepiece is fully parfocal (minimum refocusing) with the others in the series, with the exception of the 40mm model, which has been optimized for the widest possible field of view in a 1.25" eyepiece. The 55mm model has a 2.0" barrel, for telescopes with this large diameter eyepiece holder.

7.4mm Plössl	#8321
10.5mm Plössl	#8322
13mm Plössl	#8326
17mm Plössl	#8323
21mm Plössl	#8325
26mm Plössl	#8324

$86.95 ea. (2.59)

32mm Plössl	#8329
40mm Plössl	#8327

$106.95 ea. (2.79)

55mm Plössl 2" #8328 **$239** (2.79)

Orion® 45-Degree Erect Image Diagonals

NEW!

See the world as it really is with Orion's new 45-degree erect image diagonal. Upside-down, backwards and topsy-turvy images can often confuse even the stoutest and most experienced observer. Turn it right-side-up with your choice of three models to select from.

.965 Diagonal #8759 **$59.50** (2.59)

1-1/4" Diagonal #8753 **$59.50** (2.59)

Size-Adapting Hybrid Diagonal #8755 **$59.50** (2.59)

Star Diagonals

1.25" Star Diagonal
Primarily for astronomical use, lets you view at a right angle. Multi-coated, for 1.25" eyepieces.

#8763 **$39.95** (2.39)

.965" Star Diagonal
Same as 1.25" Star Diagonal, but with standard coated optics. Works with .965" eyepieces and eyepiece holders.

#8761 **$24.95** (1.89)

2" Star Diagonal

Get the widest possible field of view from your Schmidt-Cassegrain Telescope. This star diagonal features a special aluminized and overcoated precision first-surface flat mirror.

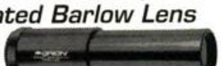
#8767 **$89.95** (2.89)

Orion® VariPower™ 2-3x Multi-Coated Barlow Lens

Our best barlow offers significant improvement over other models we've seen. The magnification is adjusted by sliding the internal lens cell along a calibrated scale (you don't have to poke a finger or pencil inside to do this). Fully Multi-Coated optics provide excellent sharpness, contrast and brightness. 1.25" diameter.

#8748 **$69.95** (2.59)

Orion® 3-element Fully Multi-Coated Barlow Lens



Fully Multi-Coated 3-Element Barlow lens provides superior imaging with precise color correction at three wavelengths. For maximum light transmission and highest contrast, we have used the finest quality multi-coating on each air to glass surface. 1.25" diameter.

#8750 **$59.95** (2.59)

Orion® Deluxe Fully-Baffled Multi-Coated Barlow Lens

Fully internally opaqued and baffled to block stray light for noticeably higher contrast. Large 27mm multi-coated 2-element lens provides 2x magnification with any 1.25" eyepiece.

#8746 **$49.95** (2.39)

Celestron ULTIMA® Eyepieces

The Ultima Series of eyepieces are hybrid designs of 4 to 7 elements. High performance, minimization of aberrations, long eye relief and a wide field. Includes 14 separate eyepieces in both 1.25" and 2.0" barrels. All Ultima eyepieces have rubber eyecups to keep out extraneous light and provide more comfortable viewing.

#8670 5 mm, #8672 7.5 mm, #8673 12.5 mm, #8674 18 mm, #8677 24 mm **$69.95** (2.59)

#8678 30 mm, #8679 35 mm, #8680 42 mm **$99.95** (2.79)

Extra Wide Field Ultima Eyepieces
#8681 15 mm-WA, #8682 19 mm-WA, #8683 23 mm-WA **$119** (2.79)

Extra Low Power 2" Ultima Eyepieces
#8689 45 mm, #8690 60 mm **$189** (2.79)

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7 x 50 FMT-SX
List: $679.95
27mm lenses

Fujinon is better by far. Every computer-designed, optical surface is electron beam coated (EBC) with zirconium oxide. 99.9% of the light striking any surface passes through. More important, 95% of the light entering the objective lenses emerges from the ocular lenses. And each model meets U.S. military specifications for strength, shock and temperature resistance, and for being waterproof.

The new F-series (7 × 50 FMT-SX and 10 × 70 FMT-SX) gives the ultimate in brightness and resolution. With flat-field optics, tangential and sagittal astigmatism and distortion are reduced to levels the eye can't detect. From center to edge, the image is perfect. For improved color correction, objective lenses have a longer focal length. Eyepieces, with 27mm ocular lenses, are comprised of 4 groups — 5 elements. With 23mm eye-relief — the world's longest — you see a full image even when wearing glasses.

In addition to Fujinon's patented EBC coating, inside the light alloy housings, surfaces are ribbed and finished in matte black. Lens and prism edges are carbon black-coated to further reduce reflections. Optional accessories include: tripod adapter, Nebura filters, vision correcting diopter attachments and haze, polarizing, and neutral density filters.

10 x 70 FMT-SX
List: $849.95

Fujinon's 25 × 150 MM Astronomical Binocular — The world's most powerful. The same binocular, with conventional instead of right-angle viewing, is used by the U.S. Navy and Coast Guard. Exit pupil: 6mm; brightness factor: 36; field of view: 2°42"; weight: 64 lbs. Suggested list: $11,000.00 including pedestal for permanent installation.

For more information, a free color catalog and the name of your nearest dealer, please contact us. If there is no dealer near you, order directly — with 10 day free trial. Major credit cards and certified checks accepted.

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Folding Porta-Chair

NEW!

Surprisingly comfortable considering its small size; this chair is ideal for astrophotographers or those who find observing while standing to be uncomfortable. An ideal addition to any amateur astronomer's observing equipment Weighs 6 lbs. and is just 22" long folded up. It opens to 1 1/2' tall with a seat 10 1/2" x 11 1/2" in size.

#5938 **$49.95** (3.60)

Popular Observer's Chairs

Make observing more comfortable and enjoyable with one of these great chairs.

Standard Model-
Has adjustable-height center column and padded vinyl seat. Folds for easy storage.

#5935 **$39.95** (3.96)

Deluxe Model-
Is much heavier-duty, built for professional musicians. Extra thick padding, wide footprint. Adjustable and disassembles for storage.

#5934 **$89.95** (5.65)

Orion® Big Eye 8x50 & 11x80 Finder Scopes

NEW!

Ideal for upgrading any telescope including Schmidt-Cassegrains. Available non-illuminated or with wireless, adjustable, battery-operated illuminated reticle and Polaris grid for accurate polar alignment. With 90° diagonal prisms. Optional deluxe dual-ring brackets are perfect for 8" and 10" Celestron or Meade; will fit many others, too.

8x50 Models

The 50mm objectives gather 2.7 times more light than 30mm finders!

8x50 Standard Finder #7100 **$89.95** (3.31)

8x50 Illuminated Finder #7135 **$134.95** (3.56)

Bracket— For 8" & 10"#5143 **$25.95** (1.89)

11x80 Models

These huge finders gulp in over 7 times the light of 30mm finders; 2.5 times more than 50mm models! You might spend more time viewing through the finder than through your main telescope!

11x80 Standard Finder#7146 **$219** (4.16)

11x80 Illuminated Finder #7143 **$269** (4.16)

Bracket— For 8" & 10" #5140 **$37.95** (2.39)

Economical 6x30 Finder Scopes

NEW!

Upgrade your refractors' small finder scope to a new low-cost achromatic 6x30 finder from Orion. Your choice of either a straight-through or right-angle model for locating astronomical or terrestrial objects 2-element color corrected achromatic objective lens for clear images. Both models utilize a .965" eyepiece with standard crosshairs. A push-pull focusing mechanism speeds the time it takes to bring you image into razor-sharp clarity.

Straight-through model	#13023	**$39.95**	(2.39)
Right-angle modl	#13021	**$49.95**	(2.39)

Orion® T-Adapter

For prime focus photography. Use with T-ring to match your 35mm camera. For Meade, Celestron 8", 10" SC.

#5116 **$27.95** (1.89)

Orion® Dew Zapper

Orion's Dew Zapper is a sure-fire cure for dew problems on your 8" or 10" Celestron or Meade Schmidt-Cassegrain telescope. Dew Zapper gently replaces lost heat, bringing the corrector plate temperature slightly above air temperature.

8" Dew Zappers- fit all Meade & Celestron 8" Schmidt-Cassegrains

DC Model #3503, AC Model #3504 **$39.95** (2.39)

10" Dew Zappers- fit all Meade 10" Schmidt-Cassegrains

DC Model #3506, AC Model #3508 **$39.95** (2.39)

Dew Remover Gun

Moisture that interferes with viewing dissipates quickly with this 12V DC, 156 watt warm air gun. Has 4-1/2' cord.

#5601 **$17.95** (2.48)

Orion FlexiShield™ Dew Caps

NEW!

Eliminate dew problems with FlexiShield! Better performance, more rugged, and easier storage than rigid dew caps. Made of durable, unbreakable, fire-retardant Kydex™. Form into a tube with the velcro closure, or change into a flat rectangle or small-diameter tube for easy storage and transportation. No paint to chip or scratch off. They fit your telescope tube snugly, thanks to the wide rubber padding and full-length velcro closure. Nothing needs to be attached to your telescope; needs no screws, no tape, no glue. Once in place, they are very rigid and do not block the optical path. Models to fit most telescopes.

90mm Celestron/Meade Spotting Scopes	#4203	**$24.95**	(2.39)
90mm Celestron Rubber Armored Spotting Scopes	#4205	**$24.95**	(2.39)
4" Meade Schmidt-Cassegrain	#4204	**$24.95**	(2.39)
8" Celestron/Meade Schmidt Cassegrains	#4200	**$39.95**	(2.39)
10" Meade Schmidt Cassegrains	#4201	**$49.95**	(2.39)
11" Celestron Schmidt Cassegrains	#4202	**$59.95**	(2.39)

Starlite Red LED Flashlight

The Starlite is the only adjustable-brightness night-vision red flashlight. Lifetime solid-state LED can't burn out. Extra efficient electronic circuit for long battery life. Uses one 9-volt battery (not included).

#5714 **$24.95** (2.11)

Astronomer's Flashlight

Indispensable and indestructible. Has special night-vision red filter and a diffusion lens for even illumination. An essential addition to your astronomy accessories. Requires 2 D-cell batteries (not included).

#5701 **$9.95** (1.89)

Rechargeable Battery Porta-Pack

12 Amp Hour Porta Pac
Ideal for operating your telescope plus higher power-consuming accessories such as an Orion Dew Zapper. Battery is encased in high-impact polystyrene. Carrying case of Cordura nylon with shoulder strap and handle. Wt. 10 lbs.

#2354 **$99 ea.** (6.23)

Orion® Dual Balance System

Unlike ordinary counter-weights, our system allows instant adjustment in both directions. Easily balances your scope to offset both piggyback loads or rear-cell cameras, 2" diagonals, and other accessories. Rigid, precision machined dovetail bar mounts to telescope in existing accessory holes.

For Meade SC 8"	#5150	**$74.95**	(4.65)
For Celestron 8" C-8	#5149	**$79.95**	(4.65)
For Meade SC 10"	#5152	**$84.95**	(4.65)

Deluxe Metal-Clad Accessory Case

With Diced Foam Insert for Custom Fit

We always thought a good quality metal-clad case for equipment would be too expensive to be practical, but we were wrong. These cases are reasonably priced and perfect for any amateur astronomer. You can keep your eyepieces, drive control, camera, and telescope attachments perfectly safe and clean. The secret is a unique "diced" foam insert that you can custom-tailor to your exact requirements.

The cases are of a strong metal-clad construction with reinforced corners and edges. Beveled closure forms a moisture and dust resistant seal. Twin latches with key locks provide extra security. Heavy duty handle. Attractive silver color, available in two convenient sizes. You'll be amazed at how much they can hold!

Regular - 16"x12"x6-1/2", wt. 6 lbs.

#5920 **$49.95** (5.09)

Replacement Foam Insert

#5928 **$8.95** (.99)

Large - 19-1/2"x12"x6-1/2", wt. 8 lbs.

#5921 **$69.95** (5.92)

Replacement Foam Insert

#5929 **$9.95** (.99)

Heavy Duty Case

Two inches of die-cut foam cradle your fork-mounted 8" Schmidt-Cassegrain telescope securely inside a case of single-piece construction, high-impact plastic. Rubber ring seal provides moisture resistance. No need to remove counterweight bar or finderscope. Room enough for eyepieces and small accessories; pocket for maps and charts; up to 4" longer than standard cases. Internal dimensions 27.5"x18"x16".

#7065 **$189** (13.60)

Deluxe Eyepiece Case

Organize and protect your valuable eyepieces and other accessories. This durable case with double hinges holds up to 10 eyepieces plus barlow. Die cut foam insert for snug secure fit.

O.D. 8-1/2"x12-1/2"x3-1/8".

#5913 **$17.95** (2.49)

Deluxe Field Tripod Tote Bag

Designed for the field tripod with padded insert to separate wedge from tripod during transportation. Specifically made for wedge combinations of Schmidt-Cassegrain telescopes up to 10" aperture. Allows storage without changing polar alignment. This blue bag is made of tear, rip and mildew resistant 100% Cordura nylon.

#15096 **$79.95** (4.65)

Orion® UltraGuider

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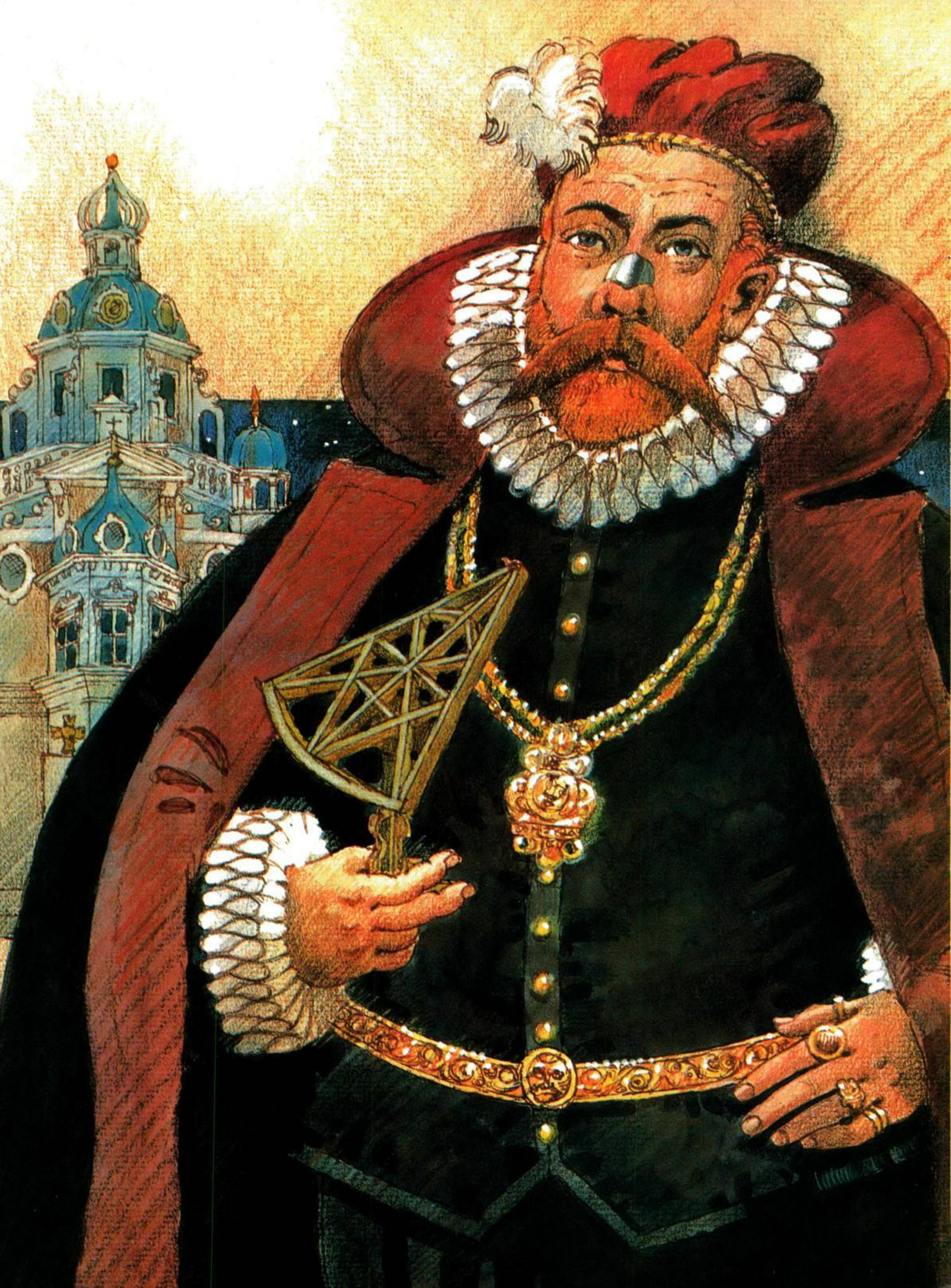
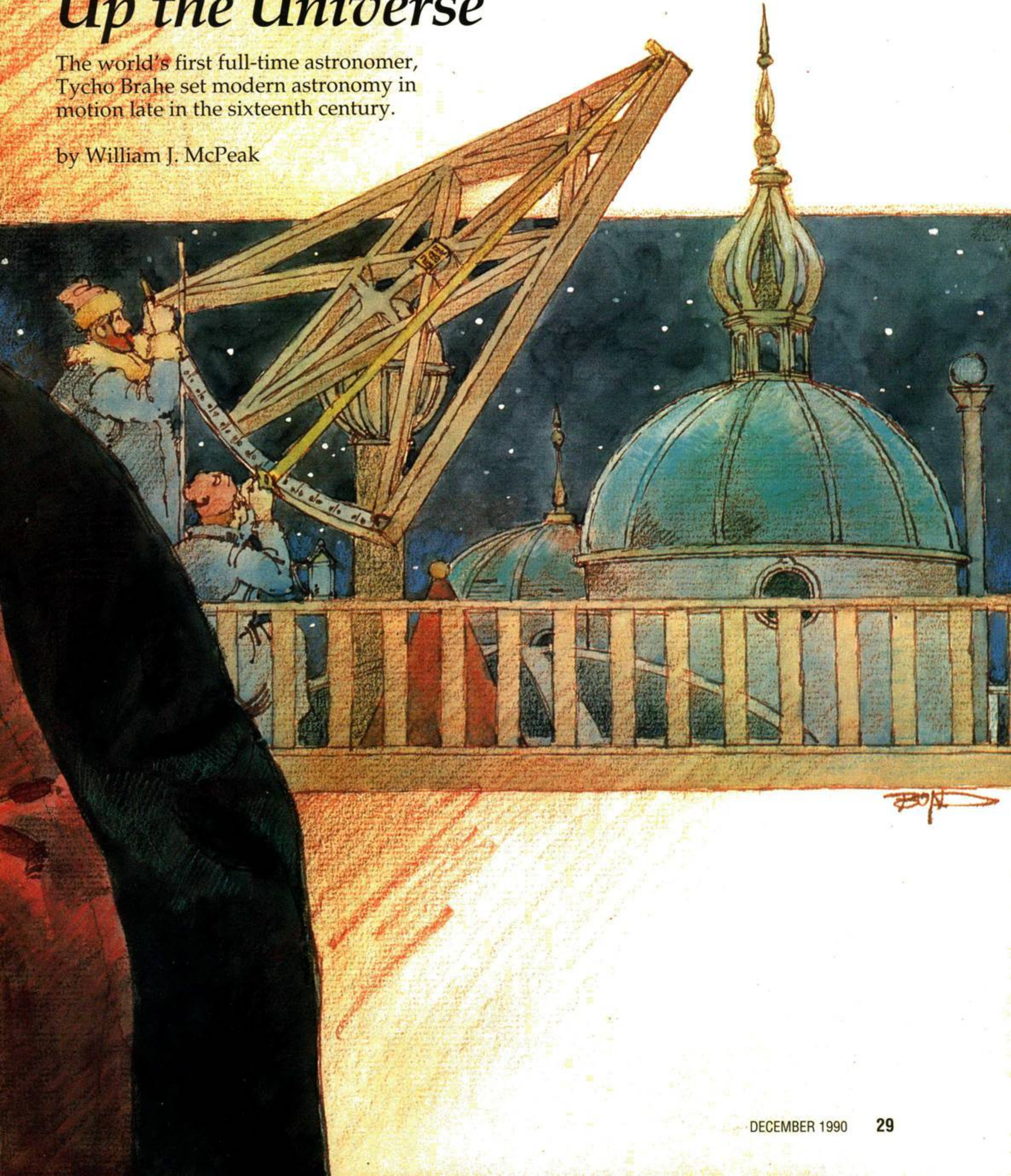


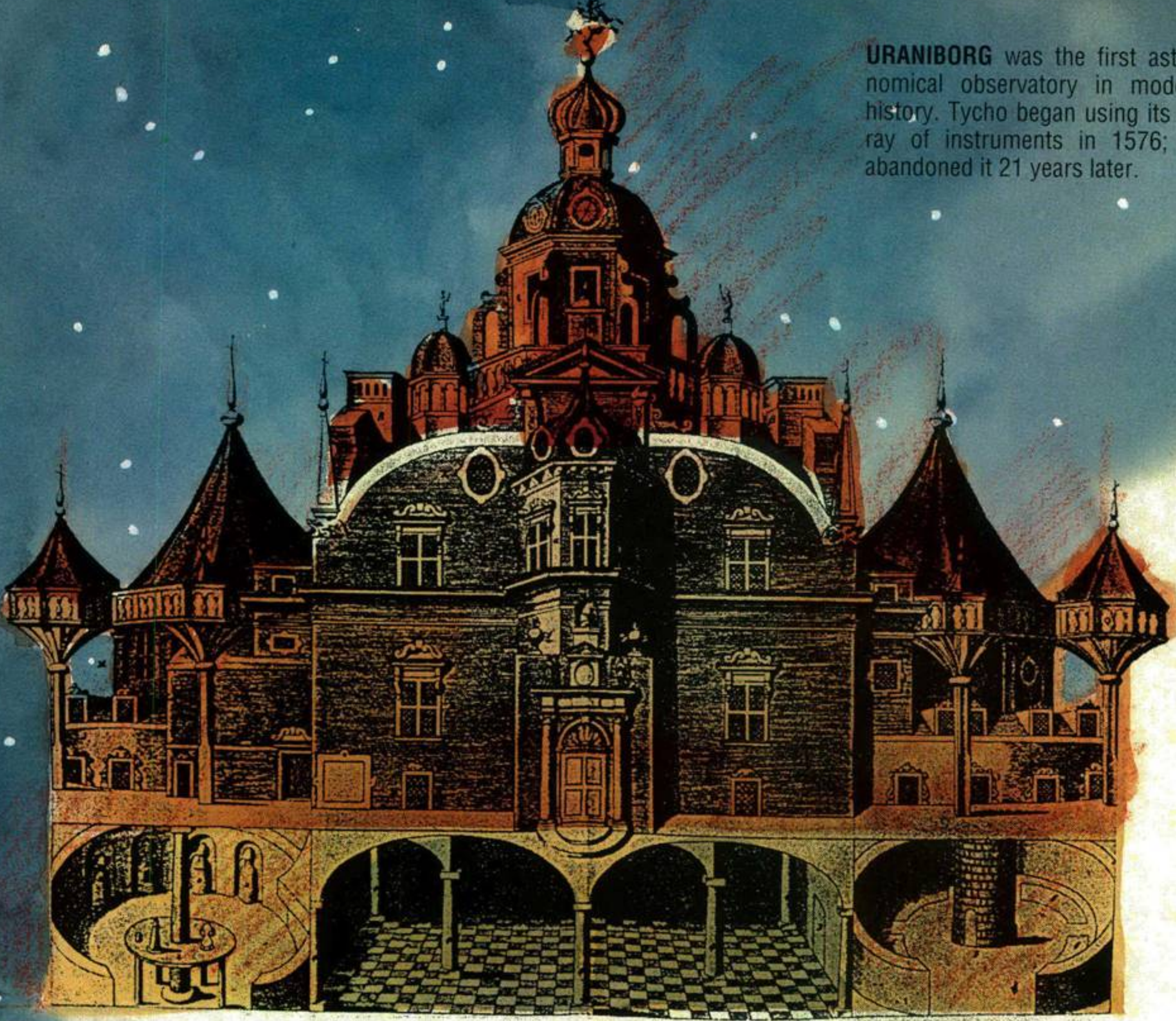
TRAILBLAZERS OF ASTRONOMY

Tycho Brahe Lights Up the Universe

The world's first full-time astronomer, Tycho Brahe set modern astronomy in motion late in the sixteenth century.

by William J. McPeak





URANIBORG was the first astronomical observatory in modern history. Tycho began using its array of instruments in 1576; he abandoned it 21 years later.

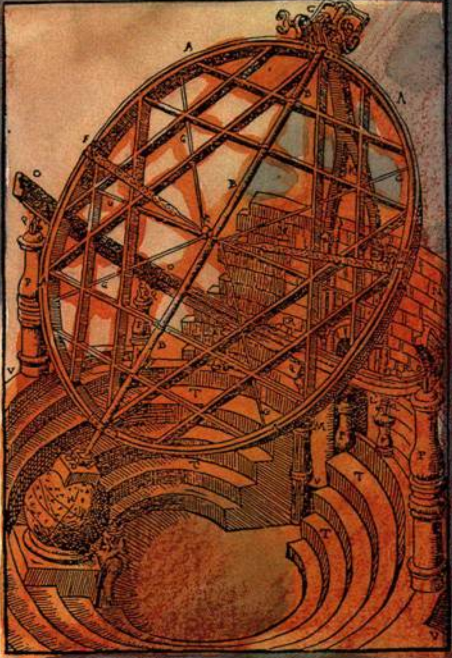
Tycho Brahe is a forgotten man. When we think of great astronomers of the past, Nicholas Copernicus, Johannes Kepler, and Galileo Galilei come to mind quickly. But what about the Dane, Tycho Brahe? Most amateur astronomers have a hard time naming his greatest accomplishments.

Despite this, Tycho was one of the all-time greats in science. He was the first full-time astronomer, founding the great observatories Uraniborg and Stjerneborg and providing them with equipment that for its time was on the cutting-edge of technology — sextants, armillary spheres, and quadrants. Tycho was the first to apply what we think of as modern systematic and qualitative observation to astronomy. He provided the first logical basis for determining relative cosmic distances and disproved ancient, primitive conceptions of comets and celestial space. And he laid the groundwork for the triumph of the Copernican revolution because he meticulously plotted solar, lunar, and planetary motions.

Born to be an Astronomer?

The eldest of eleven children of Otto Brahe, Tycho was born on December 14, 1546, at the family seat of Knudstrup in Scania. His youth was relatively comfortable. Under a family agreement, his childless uncle Jörgen acquired the responsibility for educating young Tycho. By the time he was a teenager, Tycho was sent by his uncle to the University of Copenhagen and to Leipzig to study for a career in statesmanship.

The sudden death of his uncle in 1565 gave Tycho the freedom to pursue his own education. The most painful event at school didn't involve books, however. On December 29, 1566, Tycho sought to resolve a disagreement with another Danish nobleman by duel. The two fought with swords, and Tycho lost part of the bridge of his nose. He subsequently patched the wound with a waxy form inlaid with gold and silver. Thereafter, he carried a box of salve,



TYCHO'S POWERHOUSE INSTRUMENT, his great equatorial armillary, consisted of a declination ring 9 feet across fitted with sights. He used it to determine accurate positions of stars.

frequently applying the medication to his sore nose.

Classical studies and a solar eclipse in 1560 turned Tycho's attention toward the stars. In his school days, Tycho became acutely aware of the need for accurate observations with instruments superior to the current tools used by astronomers. Naked-eye instruments, little changed from ancient times, were used as positional plotting tools. The most common instruments were a graduated arc limb with partial or full circumference and a radial ruler (alidade) with a sight at each end. The quadrant (90° arc) and the early sextant (60° arc) used by both mariners and astronomers were based on the earlier two-armed compass. These tools were used to measure angular dimensions in the sky or altitudes of celestial objects.

Other tools were somewhat more sophisticated. These included rings and armillary spheres. An armillary sphere was a globe-shaped device that provided a three-dimensional representation of the heavens as a celestial sphere, with Earth at the center. By including lines representing the celestial equator, the ecliptic, and the latitude and longitude, an astronomer could use an armillary sphere to study stars and planets relative to celestial space rather than the Earthly horizon.

These instruments served 16th-century astronomers well, but Tycho wanted to improve them. He wasn't satisfied with being a mere participant; he wanted to innovate. Tycho realized that he could gain more accuracy in his instruments by making them bigger. He set about building large versions of his instruments during the next stage of his life. He realized two key qualities for building large instruments: Graduated angular scales had to be made accurately enough to subdivide degrees into arcminutes. He also realized the need to correct for parallax and atmospheric refraction.

In 1568 Tycho built a quadrant with a radius of 14 cubits (21 feet) at Augsburg. The quadrant was so heavy that it required twenty men to set up. The quadrant pivoted at the intersection of its two arms by means of a massive beam placed vertically in a cubical wooden frame. This made it possible to sight along the arm and move the limb, which was graduated to ten-arcsecond intervals, to indicate degrees of altitude. This instrument was used in the open until 1574, when it was destroyed in a storm.

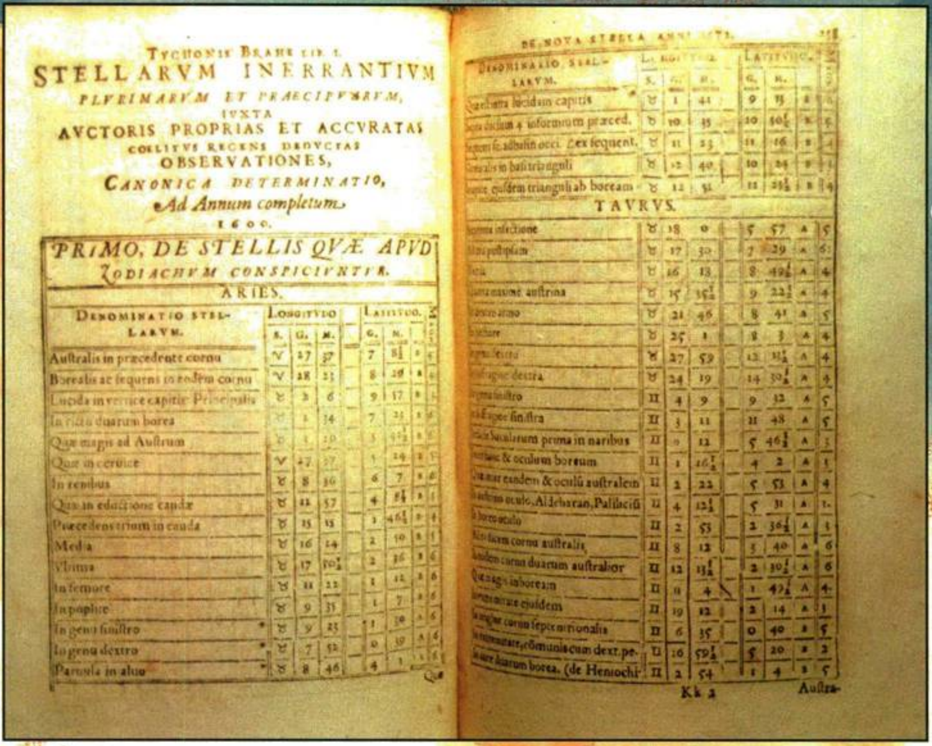
Having gained valuable experience with equipment construction and use, Tycho returned to Denmark late in 1570. On the night of November 11, 1572, his life was dramatically changed. That evening he went outside to watch the sky over Heridsvad Abbey, and he saw a star as bright as Venus in the constellation Cassiopeia. By coincidence he had just finished building a 60° sextant of walnut about five and a half feet long in the arms. This time Tycho made the eyepiece with a vertical slit for aligning the star precisely with the top of the object sight and positioned it with a hand crank. The workmanship of this fine sextant allowed him to plot the position of his new star accurately.

The new star was what we know today as a supernova. Tycho measured its angular distance from the stars of Cassiopeia in order to plot the supernova's celestial latitude and longitude. He noted as time passed that the supernova's coordinates did not change relative to the stars. Tycho published an account of the new star in late 1573, and the star finally faded from naked-eye visibility in March 1574. Tycho's supernova allowed him to accomplish two big breakthroughs: he showed that the heavens were changeable (which Aristotle had denied), and he concluded that the new star was as distant as the ordinary stars, because it had no detectable parallax.

Think I'll Build a Castle

Discovering the new star changed Tycho's attitude about astronomy. He now saw himself as completely devoted to the subject. Probably thinking of the repercussions of the astronomer's reclusive life he would now pursue — not the thing for a noble lady — he married a commoner named Christine. She eventually bore him eight children.

Tycho's fame caused by the supernova discovery resulted in an acquaintance with the king of Denmark. In February 1576, the king told Tycho that he could forget courtly duties and accept a life of isolation more suitable for his astronomical pursuits. Tycho moved to the little island of Hven, situated in the sound between Elsinore and Landskrona, in Scania.



TYCHONIS BRAHE LIB. I.
STELLARVM INERRANTIVM
PLVRIMARVM ET PRAECIPVARVM,
IVXTA
AVCTORIS PROPRIAS ET ACCVRATAS
COELITVS RECENS DEDVCTAS
OBSERVATIONES,
CANONICA DETERMINATIO,
Ad Annum completum
1600.

PRIMO, DE STELLIS QVÆ APVD ZODIACHVM CONSPICIVNTVR.

ARIES.

TAVRVS.

STELLARUM INERRANTIUM, one of Tycho's crowning achievements, was a catalog providing positions of 777 bright stars. The work was published in 1600, just nine years before Galileo began using telescopes for astronomical observation.

Funds would be forthcoming to build a great house, and the king let Tycho know that the island and its inhabitants were Tycho's for life. At that time Hven was sparsely populated by tenant farmers. Consisting of a bare 2,000 acres, it was the perfect spot to erect a monument to stargazing. Tycho decided to build a great observatory and call it Uraniborg, Castle of the Heavens.

Uraniborg was no medieval castle of thick gray walls, but a mixture of Renaissance styles. Tycho was already making observations from unfinished quarters in December 1576, although the structure was not completed until 1580. Made of red brick with sandstone ornamentation, the central residence measured 49 feet square and was 37 feet high. An octagonal pavilion was topped by an onion dome with clocks and a gilt weather vane in the shape of Pegasus.

The north and south ends of Uraniborg housed two observation turrets 18 feet in diameter and 18 feet in height. Platforms were located at the top. The roofs were cone-shaped, comprised of hinged triangular sections of wood that could be folded back for observing any part of the sky. At the outer end of each of these were two small observation towers on single pillars, sporting the same sort of roof and connected by galleries and catwalks to the platform levels of the large parent turrets.

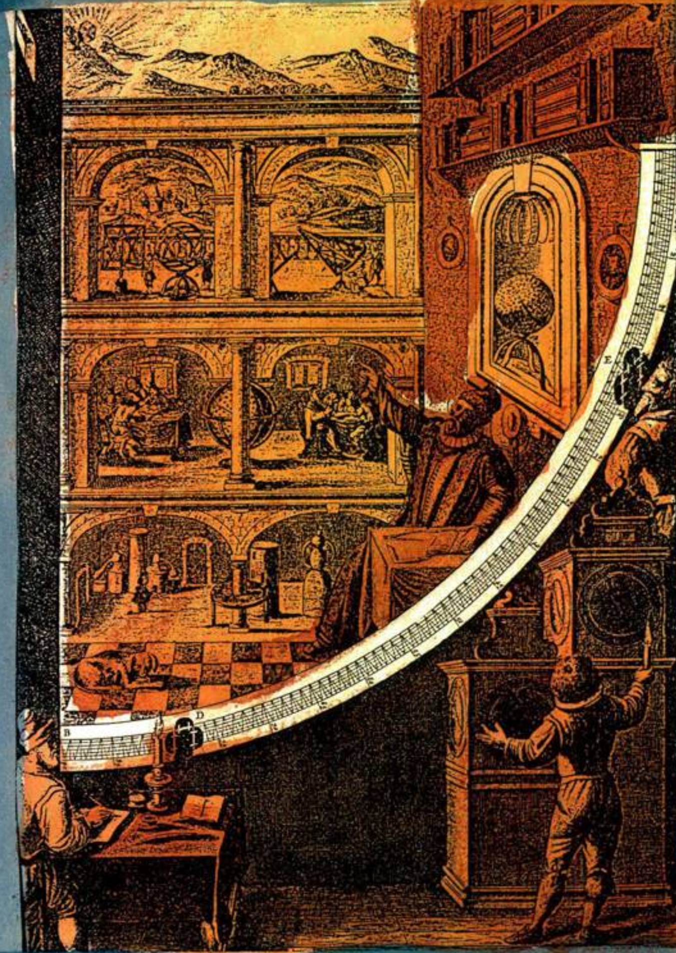
Gardens and orchards spread out 248 feet on all sides of Uraniborg and were enclosed by earthen walls 18 feet high and 16 feet thick at the base. Within the pavilion was an octagonal room with a ceiling clock and a wind indicator connected to the weather vane outside — a means of anticipating possible wind problems for the instruments. Below this, above the second-story rooms, were eight small rooms or garrets for student astronomers.

The ground floor comprised two large guest rooms, a family sitting room, and a study. The south observatory turret had a ground-floor library for study and a basement chemical laboratory. The northern observatory housed the kitchen at the ground level and a well in the basement, which provided pumped water to the floors above. Tycho's collection of instruments, often reworked at extra cost until made correctly, began to fill Uraniborg.

The observatory's library housed a great celestial globe five feet in diameter and covered in brass plates that Tycho had commissioned on his trip to Augsburg in 1570. On this globe, Tycho had his own goldsmith, Hans Crol, engrave celestial, equatorial, and zodiacal circles graduated in minutes and the positions of several hundred stars.

Uraniborg's study contained one of Tycho's most important instruments, a mural quadrant. The mural quadrant was a meridian instrument — that is, it was fixed in place on the south wall to await stars or the Sun ascending across its position, as seen through a square window cut in the wall. The graduations were marked off to ten-arcsecond intervals. For the convenience of low- or high-angle observing, two large sights could slide along the arc and were

SIXTEENTH-CENTURY ASTRONOMY sometimes had to wait for the stars: Tycho's mural quadrant, built large for greater precision, measured the position of the Sun, Moon, and stars as their light passed through a small window and onto the quadrant.



aligned with a star along a brass cylinder inserted outside the window.

Tycho was proud of this instrument and considered it an original idea. A few such quadrants had existed before Tycho's, but Tycho's was far superior. He used it as a means of showcasing Uraniborg. The observer sighted a star for altitude and called it out to the recorder. For transits across the meridian, the observer also sighted through the left slit, calling out the start of the observation to a third observer who marked the time on interregulated minute and second clocks. After the star crossed the meridian and appeared in the right slit, its position and transit time were noted as well.

The instrumentation on the rooftop observatory turrets was an impressive collection that included equatorial armillaries, four quadrants with graduated azimuth rings for altitude and azimuth positioning of stars and time determination, and a two-observer double brass and iron arc.

One Just Isn't Enough

By 1584 Uraniborg felt cramped. So Tycho constructed a second observatory on a small rise about a hundred feet south of the perimeter of Uraniborg. This was called Stjerneborg, or Castle of the Stars. This facility was comprised of a wooden enclosure 57 feet square housing five observing rooms and a central study with a brass mechanical statue of the god Mercury rotating at the top.

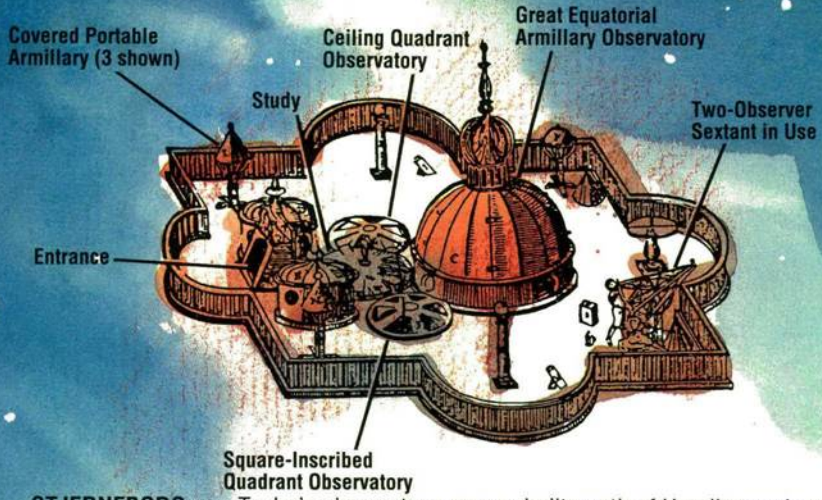
Stjerneborg's study and its three contiguous circular rooms were essentially subterranean crypts designed to protect observing instruments from wind. The crypts were supplied with circular ramps for descending and ascending along the exterior of the instruments employed at Stjerneborg. The largest of these observation rooms was built with a dome and capital like Uraniborg's. The dome was made of triangular wood segments that could be removed as necessary. This crypt housed Tycho's largest instrument, a great equatorial armillary composed of a huge, revolving iron declination ring nine feet across fitted with two sights and strutted for stability to a tubular steel axis with a brass objective cylinder sight at its center.

The other two subterranean rooms were supplied with ground-level, special-beamed, doubled skylight roofs equipped with circumferential wheels. The left room held a ten-foot diameter quadrant. The right room held a 12-foot diameter steel quadrant. These instruments joined the mural quadrant as principal tools for star transits and for determining solar orbital motion from altitude and declination observations.

Uraniborg was not only a working observatory; it was an astronomy school. Tycho felt that observing assignments given to many observers and then averaged together would provide the most reliable data. This was required for all of the stellar, lunar, solar, and planetary observations made at both of the observatories.

Employing this impressive array of instrumentation for nearly twenty years, Tycho trained observers and computers. He filled the meteorological diary and his data ledgers with plots showing solar, lunar, stellar, and planetary data. Tycho's solar observations allowed him to calculate a table of refraction corrections for each degree of altitude. From the lunar data — distances from fixed stars, altitudes, and declinations — Tycho discovered anomalies in lunar orbital motion. But lacking the gravitational theory that Isaac Newton would develop one hundred years later, Tycho could not completely account for them.

One outstanding area of neglect in Tycho's time was creating a star catalog. The basic job done by Hipparchus was then more than 1,600 years old.

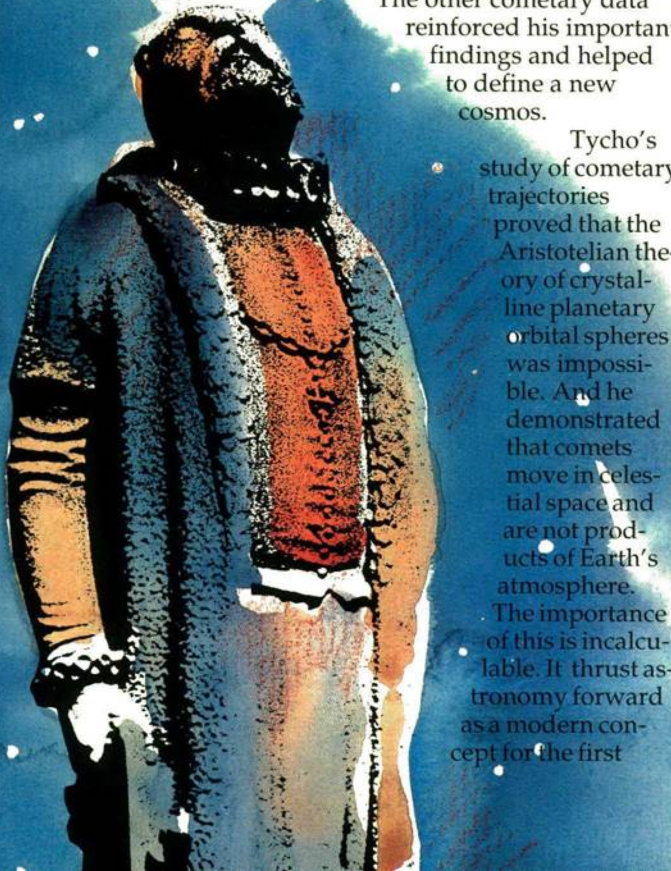

Covered Portable Armillary (3 shown)
Ceiling Quadrant Observatory
Great Equatorial Armillary Observatory
Study
Two-Observer Sextant in Use
Entrance
Square-Inscribed Quadrant Observatory

STJERNEBORG was Tycho's observatory annex, built south of Uraniborg when the original facility lacked sufficient room. It was completed in 1584.

TYCHO'S GREATEST VISUAL DISCOVERY was the "guest star" he spotted in Cassiopeia in 1572. Tycho's supernova shone as bright as Venus for several weeks, then faded to invisibility. This image shows the supernova's remains as imaged by the *Einstein* x-ray observatory 400 years later.

Using a mean value for the right ascension of Alpha Arietis as a base star, Tycho determined the positions of the nine brightest stars and twelve others close to the zodiacal circle. Between the years 1578 and 1591, he used these data to determine the right ascensions of all other prominent naked-eye stars, 777 in all.

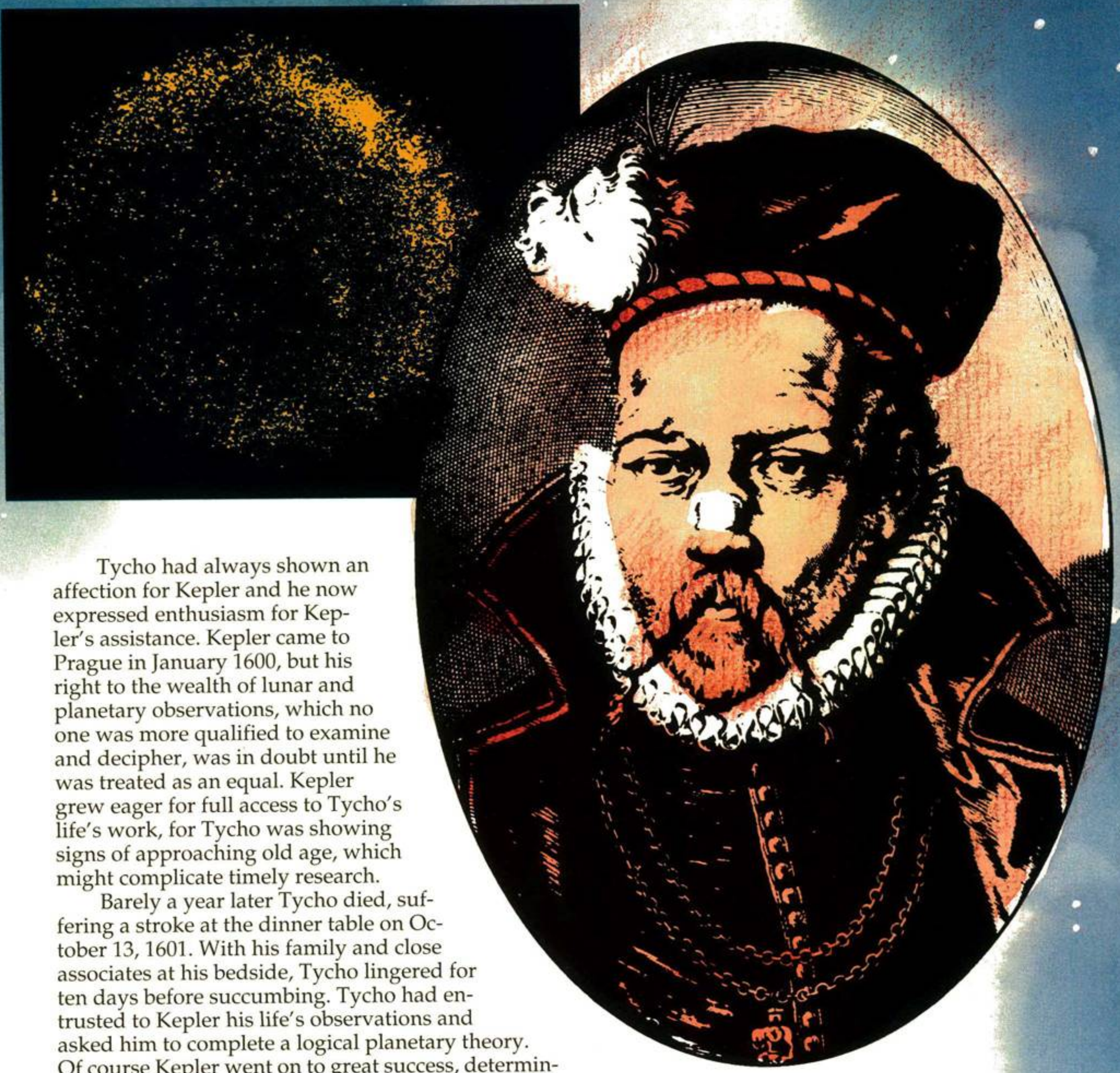
In addition to the supernova of 1572, Tycho and his assistants carefully observed positions and parallaxes of comets that appeared in 1577, 1580, 1585, 1590, 1593, and 1596. The comet of 1577 provided Tycho with his first solid physical data since the supernova to suggest serious flaws in the ancient model of the cosmos. In tracking this comet (particularly with the one-observer sextant), Tycho saw no appreciable diurnal parallax. This meant the comet cut a path through the heavens that lay beyond the Moon and must, in fact, travel through the orbits of the planets. The other cometary data reinforced his important findings and helped to define a new cosmos.



Tycho's study of cometary trajectories proved that the Aristotelian theory of crystalline planetary orbital spheres was impossible. And he demonstrated that comets move in celestial space and are not products of Earth's atmosphere. The importance of this is incalculable. It thrust astronomy forward as a modern concept for the first time. Prior to that it had roots deeply planted in unscientific thought. In one series of arguments Tycho succeeded in liberating fundamental ideas about the universe that would echo throughout future astronomy and set the stage for the eventual success of the Copernican revolution. (Ironically, Galileo still believed that comets were part of Earth's atmosphere, while Kepler could not shake off solid, geometrically arranged celestial spheres. Both were contemporaries of Tycho.) Change was a slow process, however — elder astronomers continued to try to explain away any physical data contrary to ancient conceptions.

Unfortunately Tycho did not oversee Hven carefully, being distracted by his intense astronomical work. He put off duties such as repairing buildings and treated some of his tenants with a snobbish arrogance. Consequently, though King Frederick II overlooked complaints, Tycho's brash and stubborn behavior came home to roost after the king's death in 1588. Royal cutbacks came with the new king, Christian I, and Tycho's pride over the importance of his work and resentment of criticism kept him from making apologies and compromises. This deterioration of relations precipitated Tycho's departure from Hven and his native land. He had made an insignificant island into the showpiece of Renaissance science. But Tycho had also grown tired of his isolation and wished for greater opportunities.

In 1597 Tycho packed up his family and all but the four largest instruments and made his way to Rostock with the intention of becoming Imperial mathematician for Emperor Rudolf II in Prague. The bulk of instruments and books was stored at Magdeburg, while the remaining instruments at Hven were shipped to Lübeck and then forwarded to Hamburg for shipment down the Elbe. Meanwhile, Tycho took up residence in the imperial castle Benatky, where he planned to recreate a Uraniborg-style observatory and laboratory. But instead Tycho drifted back to Prague. Desperately in need of a colleague, Tycho discovered the man who would fall heir to his legacy, Johannes Kepler. The two were not strangers. Kepler had already published his first book in 1596 on the Copernican system and was known by Tycho.



Tycho had always shown an affection for Kepler and he now expressed enthusiasm for Kepler's assistance. Kepler came to Prague in January 1600, but his right to the wealth of lunar and planetary observations, which no one was more qualified to examine and decipher, was in doubt until he was treated as an equal. Kepler grew eager for full access to Tycho's life's work, for Tycho was showing signs of approaching old age, which might complicate timely research.

Barely a year later Tycho died, suffering a stroke at the dinner table on October 13, 1601. With his family and close associates at his bedside, Tycho lingered for ten days before succumbing. Tycho had entrusted to Kepler his life's observations and asked him to complete a logical planetary theory. Of course Kepler went on to great success, determining the laws of orbital motion. Tycho's influence resonated not only in Kepler but throughout the lives and thoughts of all astronomers to come. And what of Uraniborg and Stjerneborg? Hven changed hands in 1602, 1616, and in 1645. A new dwelling called Kongsgaarden was erected from Uraniborg bricks. In 1671 the foundation of Uraniborg was still visible, though Stjerneborg was but a hollow in the ground.

During the 19th century, antiquarians unearthed the Uraniborg laboratory and the three crypts at Stjerneborg. Simple markers indicate the location of Uraniborg today. One would hardly think that 400 years ago on that deserted spot lay the world's first scientific observatory and one of the great centers of free thought for humanity. Because he established the foundation of modern astronomy, it's difficult not to feel the contributions of the lord of Hven, Tycho Brahe. ☐

TYCHO BRAHE was at once one of the world's greatest scientists and one of the world's most unusual men. Some people speculate that his testy nature and drive resulted from the ugly nose injury suffered in an early duel.

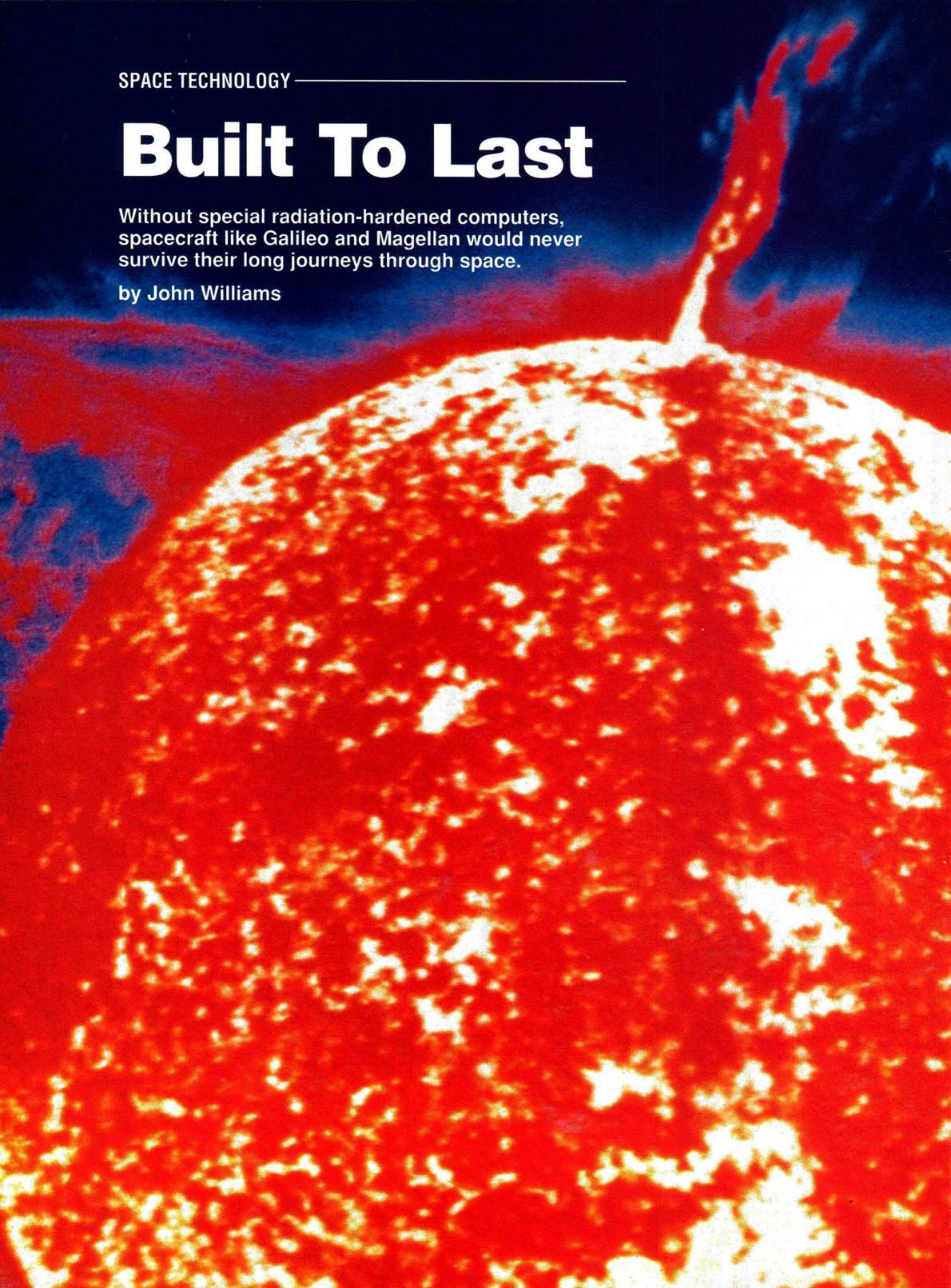
William J. McPeak is a technical author, historian of science, amateur astronomer, and former geophysicist living in Lake Forest, California.

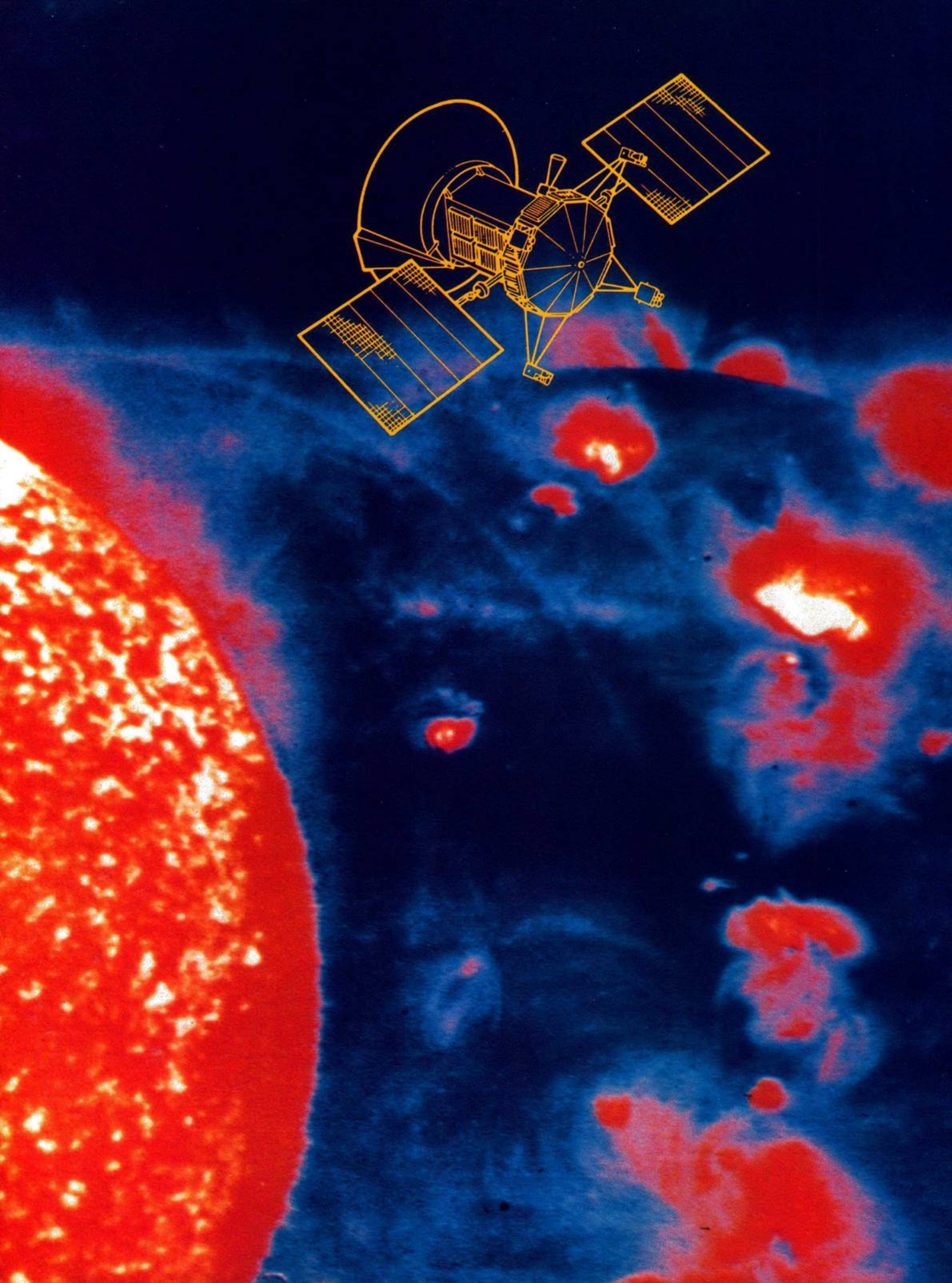
SPACE TECHNOLOGY

Built To Last

Without special radiation-hardened computers, spacecraft like Galileo and Magellan would never survive their long journeys through space.

by John Williams





Space can corrode an interplanetary probe as insidiously as salt and water do your car. Atomic oxygen eats away at spacecraft coverings, high-energy particles degrade solar panels, and dust covers everything. Even the most hardy spacecraft can be destroyed in a high-speed collision with a particle no bigger than a pea.

To survive the rigors of a years-long journey through the solar system, the components of a probe like *Voyager* or *Galileo* must be hardened to withstand high radiation, particle impacts, and temperature extremes. Since it is inaccessible for servicing, the probe must operate flawlessly under such conditions, often for many years. Ruthless testing of spacecraft parts, especially the computer components, is essential if the mission is to have any guarantee of success.

Such a guarantee does not come cheaply. As an example, you can buy one megabyte worth of memory for your home computer today for about $100. But harden that one megabyte for the space environment and the cost skyrockets to about $1 million.

A *Magellan* Memory Glitch

The most serious threat to a craft traveling through space often comes from radiation and high-energy particles knocking out the silicon memories of spacecraft computers.

Magellan, NASA's $550 million mission to map the surface of Venus, may have been hit with just such a problem. On August 16, six days after *Magellan* entered Venus orbit, ground controllers mysteriously lost contact with the spacecraft. Contact was regained after a tense thirteen hours, but another signal blackout occurred on August 21. The spacecraft systems appeared to be healthy, so engineers initially turned their suspicions to external causes: sparks from static electricity, higher-the-expected radiation around Venus, or possible hits from cosmic ray particles. Either culprit could zap a memory chip in the spacecraft's electronics, causing an on-board computer to run amok.

It's possible that the exact causes of the signal losses may never be known. NASA engineers are preparing to counter any further problems that develop during *Magellan's* 9-month mission. For example, mission engineers have programmed *Magellan's* computers with additional commands that will keep *Magellan* safe and sound during any future signal blackouts that might occur. In addition, engineers are able to write around any damaged memory cells they find.

The incidents at Venus demonstrate the concern mission planners have about radiation and high-energy particles. Hits from charged particles can create a "single event upset," or SEU, and it represents one of the most serious problems for today's advanced spacecraft.

Bullets from the Sun

In March 1989 one of the largest flares recorded since the beginning of the space age erupted on the surface of the Sun. On Earth, even observers as far south as Florida were treated to an aurora as the charged solar wind slammed into the magnetic field and spilled over the polar regions. Over the course of 1989, three intense solar flares interfered with telephone transmissions, FM radio broadcasts, and shortwave and satellite communications, and in some instances actually disrupted commercial power grids. Not since February 1956 had the Sun been so active.

In 1989 both the *Magellan* and the *Galileo* probes set sail into this storm of solar particles. It is during a time of intense solar flares that scientists most expect to see problems from particle bombardments. But particle upsets can also occur when a probe flies through a planet's radiation belts. *Voyager 1* experienced 42 single event upsets during its flyby of Jupiter. In one case the central computer was reset, causing the spacecraft clock to lag several milliseconds. Although that's not much time by earthly standards, milliseconds count in the precise maneuvering, imaging, and experimentation executed near Jupiter and its moons.

SEUs occur when computer circuits undergo what is called a "bit flip." In the binary computer language a spacecraft uses, a circuit is either on (a one) or it's off (a zero). In a bit flip, a one flips to a zero, or a zero changes to a one. Computers receive and send information in a string of ones and zeros, so an unwanted flip from one state to the other in a memory chip can seriously alter a message.

The culprits are heavy ions — either solar cosmic rays blown from the stormy Sun or galactic cosmic rays zipping in from more distant parts of the universe. The subatomic particles are extremely fast and penetrate with energies of as much as two to three *trillion* electron volts per particle. That's quite a punch. At this energy level, the particles can pass straight through the outer shield of the craft and into the delicate circuitry below, triggering a bit flip.

"SEUs are probably the most severe problem facing today's spacecraft," says Ron Draper, project manager of the joint *Comet Rendezvous and Asteroid Flyby* (*CRAF*) and *Cassini* project at the Jet Propulsion Laboratory (JPL). "Some data can be lost or the mission can be destroyed if the wrong command is sent to, say, the computer in charge of attitude and articulation." This computer, just one of many on board, keeps the spacecraft's systems pointed at the Sun for power, at Earth for communication, and at the stars for navigation. The computer also gives commands to point the scan platform, which carries cameras and science instruments. "A bit flip could cause us to point in the wrong direction," Draper says. "Conceivably, if there weren't backups to help correct the problem, the probe could die because it's pointed away from the Earth or the Sun." It almost happened to *Magellan*.

Bullet-Proofing a Probe

To reduce the risk of damage from SEUs, spacecraft designers have several options. One brute force method is to place metal shielding around critical electronic parts. However, physical shielding is not always enough. On a spacecraft, about 35 inches of aluminum would be needed to stop the more energetic particles, leaving little room for the basics of the spacecraft. So, short of building the shielding out of asteroids, the best method for constructing SEU-resistant computers lies in making the electronics themselves capable of withstanding bombardment, a process called hardening. (See "Designing Superchips.")

If neither option of shielding nor hardening is possible, engineers must write computer programs both to compensate for a possible upset in the spacecraft and to take care of the spacecraft until scientists on Earth correct the problem. If these computer routines were not included, scientists could very well end up with a dead spacecraft. Redundant components are also included, in case the other precautions don't work.

As an example, after spending $25,000 for initial tests, JPL estimated *Galileo's* attitude control system would experience 340 upsets from cosmic rays during the originally planned 27-month journey to Jupiter and 0.6 upsets during the critical 12-hour Jovian orbit insertion maneuver. *Galileo* mission scientists believed the computer could not react quickly enough to an upset with only self-correcting software, so they set out to harden the parts against radiation effects. Two years later the redesigned computer system was expected to have no more than one upset during the trip to Jupiter with an almost nonexistent chance of an SEU upon its arrival. "In almost all cases we were able to shield the parts of *Galileo* to appropriate levels," says John Zipse, an engineer with the *Galileo* mission.

"We were carefully watching *Galileo* right after launch during a large solar flare and watching the counter in the attitude control system to see if it failed," Zipse says. "We were looking for any instance of single event upsets, and we didn't have any. We tolerated what was a very high SEU environment without any problems. It was a good acid test right out of the gate." In fact, mission scientists are confident that *Galileo* will be nearly impervious to SEUs, both from the Sun en route and at its destination around Jupiter.

Danger: Radiation

SEUs are just one hazard a probe like *Galileo* faces. Heavy ions that cause SEUs can be encountered at any point during a mission, but near a planet with a strong magnetic field a spacecraft can also be immersed in electromagnetic radiation like x rays and gamma rays. At Jupiter, for example, *Voyager* found radiation levels that were much more intense than scientists had expected.

"When that realization hit home," Zipse says, "we did a systematic study of every part of the *Galileo* spacecraft, to decide if it would tolerate that kind of radiation. And you really need to appreciate the levels of radiation we are talking about here. When you get a chest x ray at the doctor's office, we're talking about a few millirads — not a lot of radiation. At Jupiter, it's hundreds of thousands of rads."

Radiation of this strength causes a slow degradation of spacecraft electronics. Long-term exposure to an intense dose of x rays or gamma rays adds a permanent trapped electrical charge to the silicon oxide of the transistors, changing the way they turn on and off. The result is a decrease in a computer's speed and an increase in its power requirements.

The environment at each of the planets is different, so each mission has its own requirements for instruments, size, speed of the computer, and the computer's radiation hardness. Draper says that while the radiation expected for the upcoming *CRAF* and *Cassini* probes will be pretty benign — around 15 kilorads — *Voyager* had a 75-kilorad requirement and *Galileo* is designed for a 150-kilorad environment. He adds that the computer chips used on *Galileo, CRAF,* and *Cassini* can withstand doses of up to one thousand kilorads over an entire mission.

Sometimes circuits can recover from a strong dose of radiation and return to their normal states. At other times, however, the component gets worse even after the radiation is no longer present.

This problem arose during testing of parts for the *Galileo* probe, according to Jim Coss, acting group supervisor of JPL's radiation effects testing group. Scientists were testing random access memories, or RAMs, which normally needed a minimum of 2 volts to operate. After being irradiated, however, their power requirement rose to 3 volts. After a part sat around on the test bench for a while, it had degraded so much that it required almost the entire 10-volt power supply to be turned on. Some components degrade so much that there simply is not enough power available to turn them on. With *Galileo*, the problem was remedied by adding shielding and radiation-hardened chips.

Simulating Space

Cosmic ray particles and radiation don't cause much of a problem here on Earth because our atmosphere shields the surface very effectively. So to simulate a space environment on Earth, scientists take the cover off the computer part and bombard it with high-energy particles from a particle accelerator to test for SEU resistance. By hitting the component with different kinds of particles, engineers can find its threshold.

Several kinds of particles are used in SEU tests. Collisions with krypton ions are considered the best test because krypton ions are heavier than iron, the heaviest particles a spacecraft is likely to see. Under such strenuous tests SEU problems can be found immediately. Either the part flips or it doesn't. A good chip for *CRAF* and *Cassini*, according to Coss, will not flip when hit with a hail of krypton ions. That standard was developed during the testing of parts for *Galileo*.

In testing spacecraft, engineers must simulate not only the environment the probe will encounter but also the length of the exposure. For *Galileo*, components need to survive 9 years or 80,000 hours. If you include all the time for delays and testing, the parts will need to function for nearly twenty years.

Since they can't wait seven to ten years while a part sits during testing, engineers take a sample of the computer system and perform accelerated life tests.

With *Galileo*, the sample parts were stress tested for 2,000 hours at 125 degrees Celsius. Subjecting the parts to temperatures higher than those expected on the actual mission speeds up their wear. This allows engineers to predict the life of the components flown in space. *Galileo's* parts operated for 350,000 hours of simulated time. During that time JPL engineers detected no significant failures.

In addition to using higher temperatures, engineers also accelerate test times by exposing components to much higher dose-rates of radiation. A typical space environment would deliver less than one millirad per second to a spacecraft. In the laboratory a cobalt-60 source blasts the part with 100 rads per second while an x-ray source can deliver a 1,000-rad-per-second dose. By combining high radiation with high temperatures, engineers can simulate some seven years of space exposure in only a few minutes.

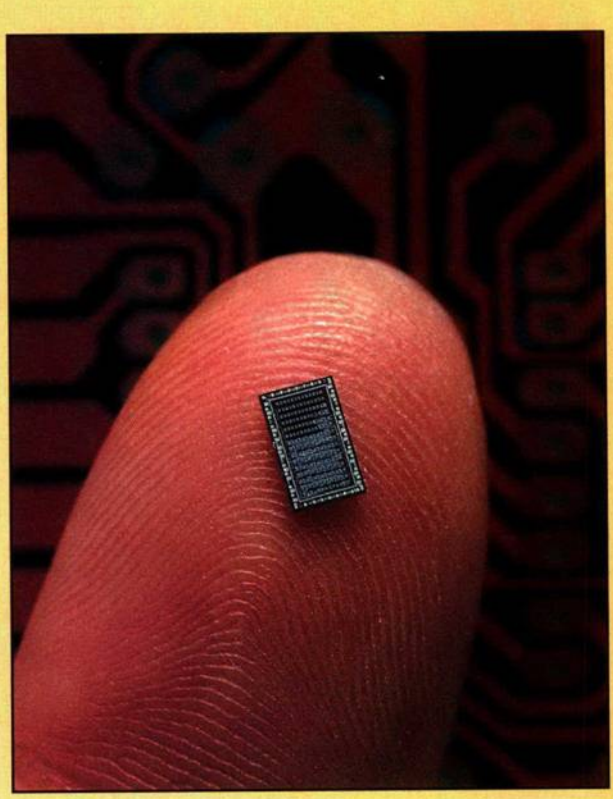
Is Newer Better?

Voyager's on-board computers consisted of about 100,000 transistors. *Galileo* is a bit more sophisticated, with the equivalent of a million transistors. Spacecraft like *CRAF* and *Cassini* will be made up of chips with tens of millions of tiny transistors.

Despite the growing sophistication of spacecraft electronics, NASA's philosophy has always been to use proven technology. In some cases this has resulted in the computer systems of space probes lagging behind their desktop counterparts by 10 years or more. Computer buffs are quick to point out that home and school computers have more computational ability and speed than most computers currently in space. According to Coss, "*Galileo* in reality is the most advanced bird we've launched, but if you look at its basic technology, it is 10 years old."

What the computer buffs don't realize is that the problems NASA has to contend with in building spacecraft are very different from those faced by designers of computers for the consumer market. NASA has to factor in the development and testing of hardware capable of surviving in space, the long spacecraft

Designing Superchips



Better computer chips have evolved since *Galileo* was designed, so the next generation of space probes will use the latest family of hardened electronics. The SA3300 chip, still under development at Sandia National Laboratories in Albuquerque, New Mexico, will combine speed, memory capacity, and radiation hardness.

The SA3300 is a version of a National Semiconductor chip, the 32C016, that has been available since 1986. According to Fred Sexton and R. Keith Treece, both Sandia staff members, the SA3300 functions exactly the same as the commercial part but has been hardened to withstand the high-energy particle- and radiation-filled space environments.

In the SA3300 each tiny transistor is about 10 by 1.25 microns across, about the size of a bacterium. The dot over the letter "i" could hold about a thousand of the 70,000 transistors making up the SA3300. At this tiny size, information stored in the computer circuits is easily scrambled by the spurious charges produced when a high-energy particle crashes through the chip.

To overcome the chip's sensitivity to SEUs, engineers have added capacitance or resistance to the circuits. A capacitor allows the spurious charge to dissipate more quickly, while resistors can slow that particular circuit down just enough — only a couple hundred trillionths of a second — so it will ignore the transient charge as the particle passes through.

To protect it against unwanted electrical charges from intense radiation, the SA3300's 200-angstrom-thick (20 billionths of a meter) oxide layer uses a special design at critical junctions to help dissipate charge buildup.

Both the *Mars Observer* mission and the *CRAF* and *Cassini* probes will use the data-handling abilities of this faster, more advanced chip.

development cycle, and launch delays. All these mean that the very latest technology often cannot be incorporated into the latest space probe. Design specifications have to be fixed years before launch.

But launch delays can sometimes help engineers bring spacecraft up to date. *Galileo* was approved in 1977 to be launched in 1982. The date slipped to 1984 and then to 1986 before the *Challenger* accident pushed the mission back even further. During that time scientists learned that Jupiter's environment was more harsh than expected. As a result, newer radiation-resistant chips were installed. The *Galileo* that was finally launched in 1989 was quite different from the craft that would have been launched in 1982.

But even if spacecraft engineers were able to use the latest and most sophisticated computer chips, the increase in performance might not be worth the risk. As Coss points out, "I don't know how well some of the stuff we're looking at now for future missions would survive."

The problem is that as the missions become more complex, the demands on the performance of the circuitry become greater. For example, the *Voyager* missions provided more information on the outer planets than had ever been written. But *Magellan* will provide even larger volumes of data, this time about one planet, Venus, while *Galileo* will flood Earth with more information than all previous planetary missions combined. To accomplish such a workload, engineers are turning to smaller, more powerful chips. But will they be as reliable?

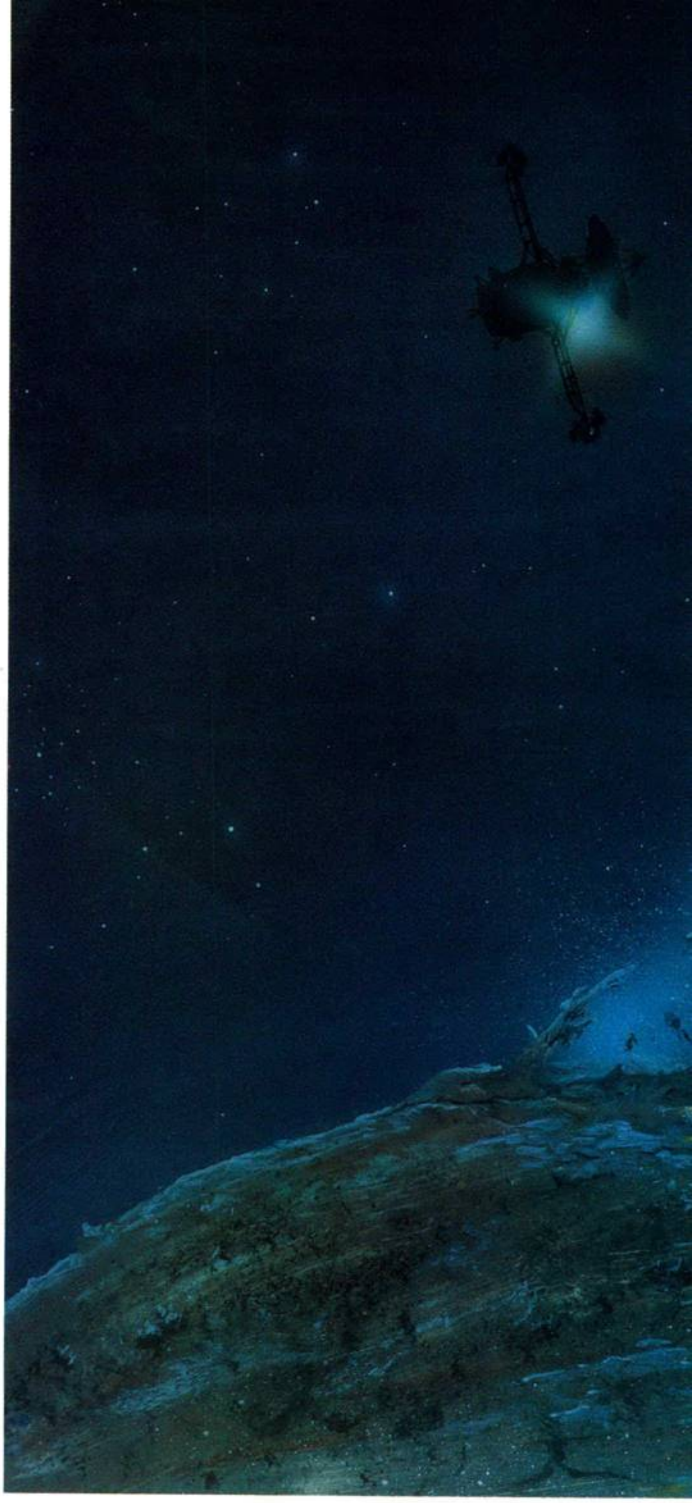
"In our constant search for devices that are faster and more complex, and which draw less current," said Coss, "we are making them smaller and smaller. This makes them more sensitive to radiation." Seeking state-of-the-art performance without sacrificing proven reliability is a constant tradeoff. But by being conservative in their designs, and by taking the time to build space-ready hardware, the technical wizards that brought us the successes of *Voyager* and *Viking* will ensure that the super-smart spacecraft of tomorrow will survive the hazards of flight. ☐

John Williams is an editor and science writer living in Jefferson City, Missouri.

VOYAGES TO THE WORLDS OF ICE

Two new space probes promise to be the *Voyagers* of the new century, exploring the icy realm of comets, Saturn's rings, and one of the largest moons in the solar system, Titan.

by Robert G. Nichols



We are entering a new phase of planetary exploration. The relatively easy missions are behind us. Ahead in the 1990s and in the new century lies a series of challenging and ambitious unmanned space projects.

While the *Voyager* probes may well be considered NASA's crowning achievements in planetary exploration, the fact is they were relatively simple spacecraft that flew conservative flyby trajectories. Surpassing the *Voyagers'* accomplishments will take much more complex missions. Thirteen years after the *Voyagers* were launched, the first of these new missions is finally underway. Launched in October 1989, *Galileo* will orbit Jupiter and study the Jovian system for 22 months. However, we still have some time to wait before its main mission begins — it will not reach Jupiter until December 1995.

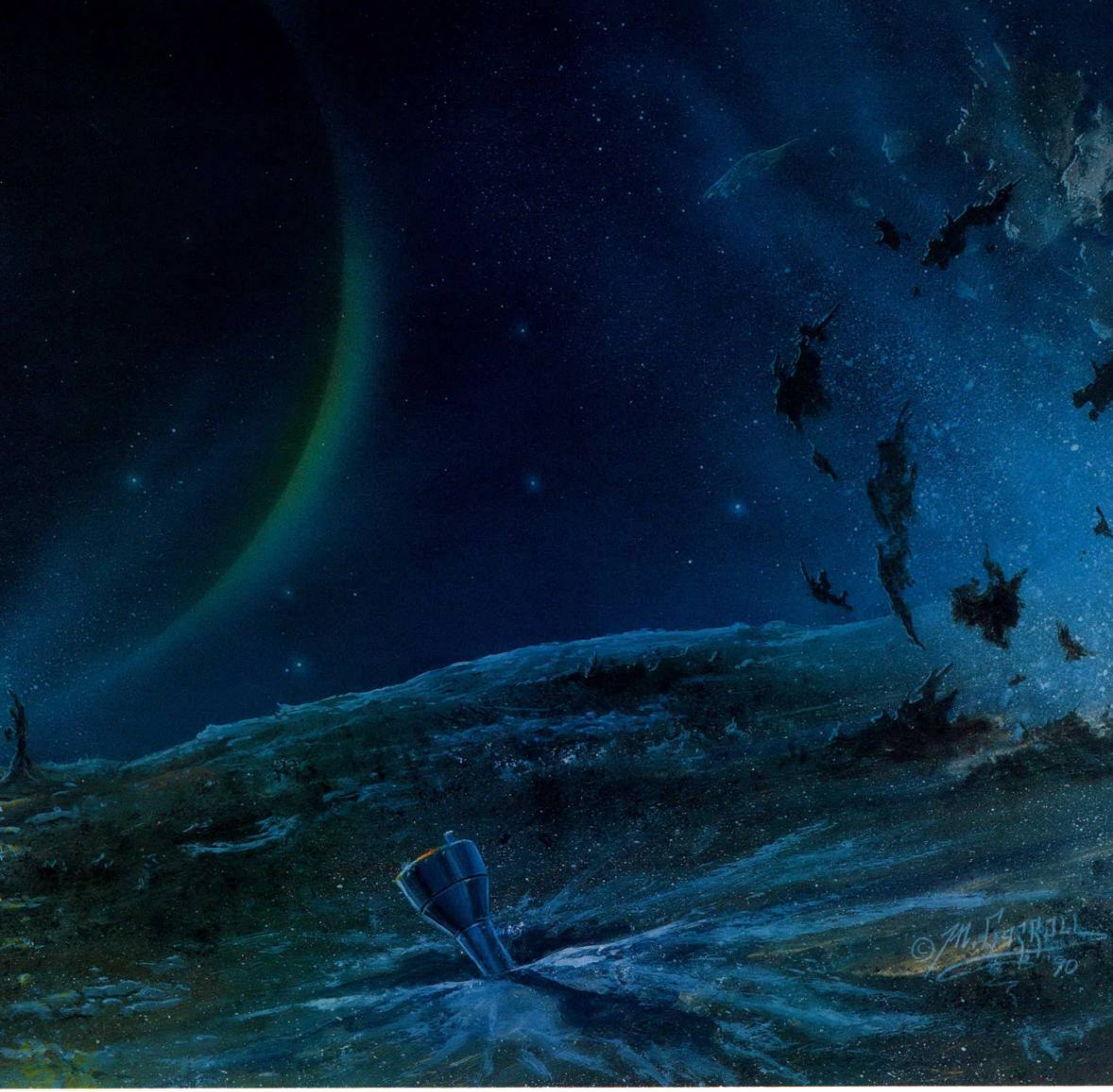
The climax of the CRAF mission will be contact with a comet.

In the meantime, NASA has started work on two more deep space orbiter spacecraft, the *Comet Rendezvous/Asteroid Flyby* (*CRAF*) and *Cassini*. *CRAF* will fly by the asteroid 449 Hamburga and then spend nearly one thousand days studying Comet Kopff as it travels toward and away from the Sun.

The planet Saturn is the destination of *Cassini*, a space probe named for the 17th century Italian astronomer who discovered the main gap in Saturn's ring system and four of Saturn's moons. Over the course of four years, the *Cassini* craft will orbit the giant planet, scrutinize its satellites and rings, and send a probe into the hazy atmosphere of Saturn's largest moon, Titan.

At the start of the design process in the mid-1980s, NASA decided on a new approach for the *Cassini* and *CRAF* missions. Instead of developing unique spacecraft for each mission, space agency officials have decided to build the vehicles around a common design called the *Mariner Mark II*. This design was developed specifically for unmanned exploration of the outer planets, asteroids, and comets, according to Ron Draper, manager of the *CRAF* and *Cassini* projects at the Jet Propulsion Laboratory. The *Mariner Mark II* is a modular chassis with common control, propulsion, and communications systems. The craft are tailored to specific missions by mounting different instrument packages to the basic chassis.

There are also monetary reasons for using the common *Mark II* design. As Draper pointed out, "We can save more than $500 million by constructing the two spacecraft around the *Mariner Mark II*." The combined development cost for *CRAF* and *Cassini* will be about $1.6 billion.



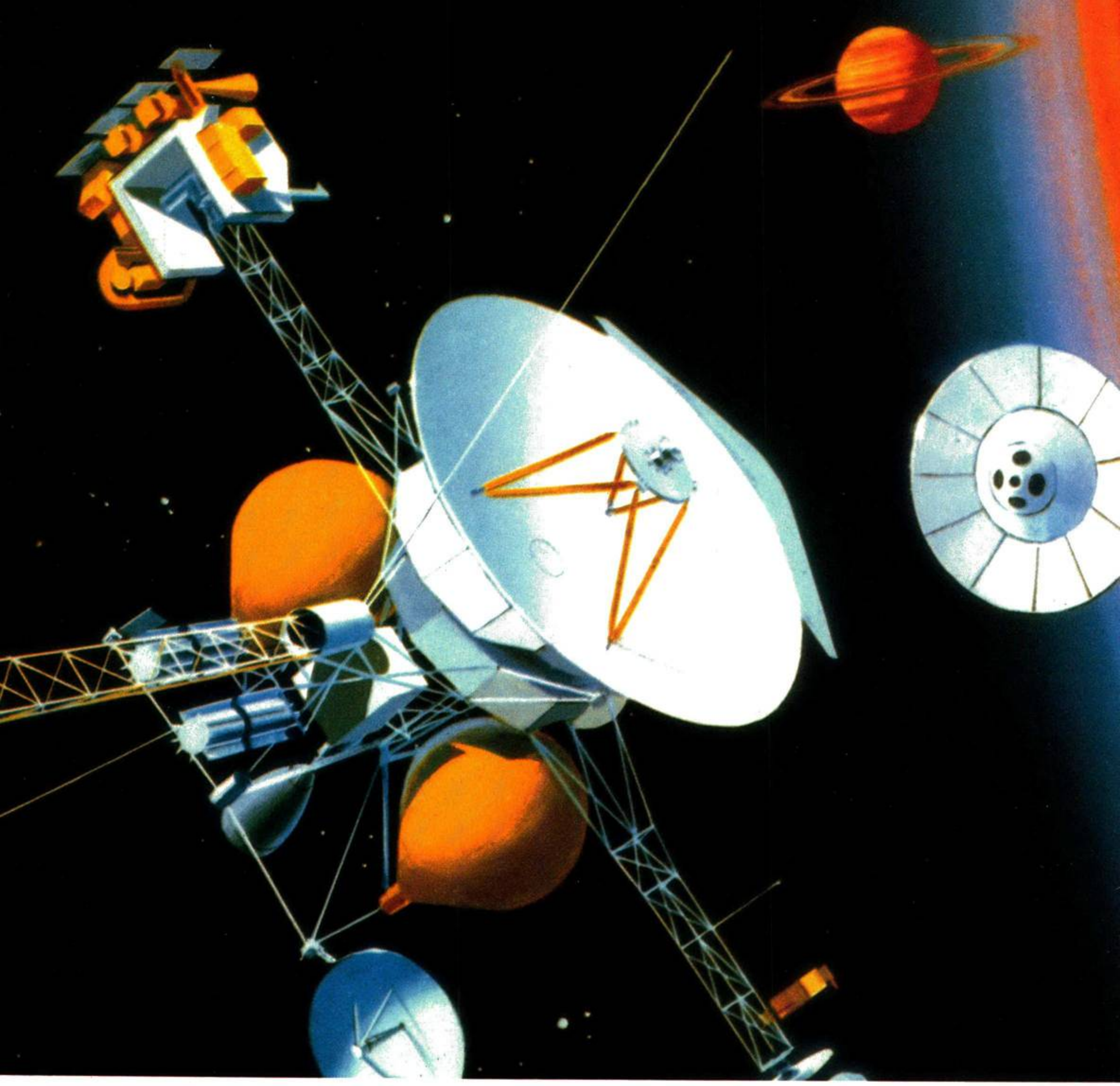
HALOES OF ICE CRYSTALS hang in the sky as *CRAF* fires its penetrator into the nucleus of comet Kopff. Painting by Michael Carroll.

Mission to the Primitive Worlds

As currently planned, *CRAF* will be launched aboard a Titan IV Centaur rocket in August 1995. If that launch window is missed, *CRAF* could be launched the next spring, though it would then target a different comet. Its flight to the outer solar system will not be a direct one. In July 1997 *CRAF* will swing by Earth for a gravity boost that will give it the velocity needed to reach its targets, a flight maneuver also used by *Galileo.*

CRAF's first target is 449 Hamburga, a carbonaceous class asteroid 53 miles in diameter. This type of dark asteroid is thought to be made of material unchanged since the solar system's formation. As it speeds by Hamburga in January 1998, *CRAF* will use its battery of remote sensing instruments to study the asteroid's composition and photograph its surface, giving us our first close look at a main-belt asteroid.

In August of the year 2000, *CRAF* will be nearly five times farther from the Sun than Earth (at 5 astronomical units, or AUs) in the general vicinity of Jupiter's orbit. At that point *CRAF* will reach its second target, Comet Kopff. At rendezvous, *CRAF* will fire its rocket motors to place it in essentially the same orbit as Kopff. *CRAF* will then accompany the comet on its fall toward the Sun.



The rendezvous will take place approximately 850 days before Kopff reaches perihelion, when the comet is still in a quiescent state. Exactly when and where the rendezvous takes place will depend on Kopff's exact orbit (gas jets from comets can change their orbits slightly) and how quickly *CRAF*'s instruments can locate the dark comet nucleus.

Even after Kopff is located, the rendezvous won't take place immediately, explains Marcia Neugebauer, project scientist for *CRAF*. "When we first get there we'll make several slow flybys closer and closer until we get enough data to determine the mass of the comet's nucleus." This is essential for determining the final orbit. "The orbit around the nucleus will have something like a ten-day period," Neugebauer says. "We expect the radius of the orbit to be 30 to 60 miles."

During the following year (340 days according to the tentative schedule), *CRAF* will observe the comet's nucleus, which scientists believe has a diameter of about 6 miles. An infrared mapping spectrometer will enable scientists to identify minerals and ices on the surface. One of the most exciting achievements will be a map of the entire nucleus. The high-resolution camera should show surface details with a resolution of three feet. When *CRAF* moves in closer to the nucleus, it will take images of selected regions. According to Neugebauer, "On those images we should be able to see things as small as 2 inches across."

Taking a Stab at a Comet

During this period, scientists back on Earth will study the images of the nucleus in order to select a

ABOVE THE CLOUDS OF TITAN the *Huygens* probe begins its descent to the surface of the mysterious moon, while *Cassini* continues to orbit Saturn. NASA illustration.

suitable target for the high point of the *CRAF* mission — contact with the nucleus itself. *CRAF* is scheduled to carry a penetrator probe designed to breach the surface of the comet's nucleus. Neugebauer described the penetrator as a "miniature spacecraft carrying a few instruments." Using a small rocket motor, the penetrator will accelerate toward its target on the nucleus. "It's pointed at the tip so that it will go a foot or so into the surface. However, it is flared at the end so it won't go in too far," Neugebauer explains. Its batteries will allow the penetrator to operate for nine days on the surface of the comet.

One of the instruments on the penetrator will be an accelerometer. This will measure how quickly the penetrator decelerates as it breaks through the comet's surface and thus will give scientists an idea about the surface composition. The tip of the penetrator will hold a gamma ray spectrometer. As cosmic rays bombard comet material, they break up the material's atoms. As a result, the atoms emit gamma rays, with each element sending out gamma rays that are specific to that element. In this way, the spectrometer will tell scientists how much of which element is in the material surrounding the penetrator.

The penetrator will also have a small claw to scrape samples of the surface material and place them in a chamber. One experiment will heat up the sample to see what happens when the icy comet stuff vaporizes. Then a gas chromatograph will sniff the gases released from the sample to determine their composition.

After the penetrator has shut down and as Kopff continues on its journey toward the Sun, *CRAF* will leave its orbit around the nucleus and begin a 50,000-kilometer journey down the developing coma. This is a region that was not well studied by the armada of spacecraft that flew past Comet Halley.

Cassini will arrive at Saturn in December 2002, over two decades after Voyager 2's brief visit.

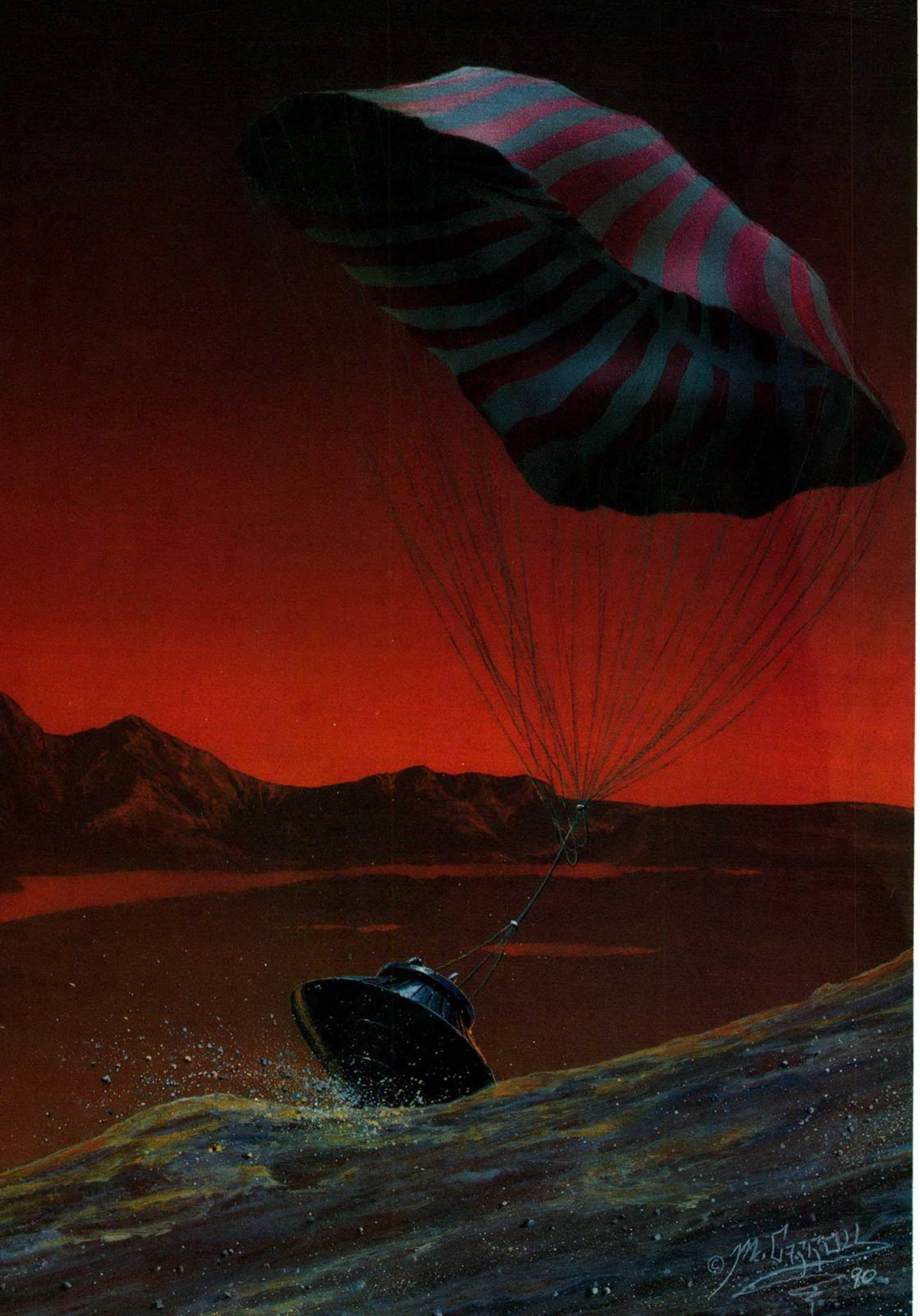
During this period, *CRAF* will use three sets of instruments to sample and study dust particles blown off from the comet. A miniature electron-scanning microscope will observe the comet's dust one grain at a time. Scientists are particularly interested in how these dust grains compare with meteorite grains and other particles of extraterrestrial origin.

Another science package will use x rays to analyze dust samples. A third instrument, the Cometary Matter Analyzer (COMA), will observe the dust through a technique called secondary ion mass spectroscopy. In this experiment, the dust is bombarded with ions and the mass of the ions knocked off the dust's surface is measured.

Neugebauer says that the "nominal end of the *CRAF* mission is 109 days after perihelion." She cautions, however, that the cutoff date is really for budgetary purposes. NASA's deep space probes have a habit of operating well after their design life. Neugebauer expects that if *CRAF* is still functioning and if funds are available, the spacecraft would be maneuvered back to the comet's nucleus where its cameras will study the nucleus again to see if any surface features changed during its close approach to the Sun.

Return to the Ringed Planet

The second of the outer planet duo, *Cassini*, will be carried aloft aboard a Titan IV Centaur launch vehicle in April 1996. Two gravity assists will be necessary before *Cassini* can reach its destination. In June 1998 *Cassini* will fly by Earth for the first gravity assist. As a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HUYGENS TOUCHES DOWN on the surface of Titan. While primarily an atmospheric probe, *Huygens* may continue to broadcast from the surface. Painting by Michael Carroll.

bonus, before it makes its Earth flyby, *Cassini* will pass within 2,000 miles of the asteroid Maja. In February 2000 it will get another boost as it passes within 2 million miles of Jupiter. Finally, in December 2002, *Cassini* will arrive at Saturn, more than two decades after the last spacecraft, *Voyager 2,* visited the ringed planet.

Once at Saturn, the mission is scheduled to last four years. During that time the spacecraft will orbit the ringed planet 36 times. It will also release a probe that will enter Titan's atmosphere. The probe is named *Huygens,* after the 17th-century Dutch astronomer who discovered Titan, and is being developed by the European Space Agency. Its main mission will be to study Titan's atmosphere.

NASA and ESA haven't selected the final instruments for *Cassini* and *Huygens.* However, a joint U.S and European science team has proposed a preliminary package of instruments, fifteen for the *Cassini* orbiter and nine for *Huygens.*

We may see pictures of the Titanian surface as the probe breaks through the cloud deck.

The instruments on *Cassini* itself will be designed for a complete survey of Saturn's atmosphere, magnetic field, ring system, and icy moons. As with *Voyager,* cameras and spectrometers mounted on a movable scan platform will look at the temperature and composition of the atmosphere as well as observe global winds and large-scale cloud structures. This weather watch will go on throughout the mission and will help determine what Saturn is like down below the clouds.

During its first three years in orbit, *Cassini* will stay pretty much in Saturn's equatorial plane. This will give the spacecraft an excellent opportunity to observe the icy satellites. There will be some 30 flybys of satellites during which the spacecraft gets to within tens of thousands of miles of its target. "We are going to target four very, very close flybys, two of Iapetus, one of Enceladus, and one of Dione," said Linda Horn, assistant study scientist with *Cassini.* Each close encounter will take *Cassini* within a few hundred miles of those moons.

Though it will start in an equatorial orbit, *Cassini* will change its orbital inclination so that by the fourth year it will be in an orbit inclined 85 degrees to the equator of Saturn. The high inclination "will allow us to probe high latitudes in the magnetosphere," explained Horn, "Saturn has a nearly symmetrical magnetic field. The magnetic dipoles are almost perfectly aligned with the planet's rotation axis." This is unusual among the planets.

The high-inclination orbit in the latter part of the mission will also give *Cassini* a better angle to view Saturn's complex system of thousands of rings and ringlets. *Voyager* first revealed this intricate structure; *Cassini* may give scientists enough information to finally understand it.

Descent to Titan

In a mission of spectacular finds, the exploration of Titan will be a dramatic highlight. Instruments on both the orbiter and the *Huygens* probe will look at what Titan's atmosphere is made of and search for complex organic molecules. A synthetic aperture radar on the *Cassini* orbiter will map the haze-covered surface of Titan with a resolution of several miles, with portions of Titan imaged to a resolution of 500 feet. This radar-imaging instrument is similar to the one being used by *Magellan* to map the cloud-covered surface of Venus.

The *Huygens* entry probe itself will be released early in the Saturn encounter. As the probe descends to Titan's surface by parachute, most of *Huygens'* instruments will focus on the atmosphere. However, a proposed camera system will take panoramic pictures of the Titanian surface as the probe breaks through the cloud deck. Horn said there is also a proposal for a surface science package. "If the probe survives the landing," she says "such a package could give us invaluable information about the composition of Titan's surface."

Beyond Saturn

Space exploration is by nature an optimistic enterprise. Looking even further into the future beyond *CRAF* and *Cassini,* NASA is considering several other international missions to explore the outer solar system. One is a joint NASA/ESA project called *Rosetta,* a comet sample return mission. A spacecraft built around a *Mariner Mark II* would travel to a comet and deploy a smaller vehicle which would descend to the nucleus and pick up a sample. The small craft would then return the sample to Earth where it would be analyzed by scientists.

Other *Mariner Mark II*-based missions might include orbiters bound for Neptune and Uranus and possibly a vehicle outfitted for an extended visit to several asteroids in the asteroid belt. NASA could even use the *Mariner Mark II* design for a mission to Pluto. But as Draper points out, "I think that it will be done someday, but I don't think that it will be done in the near future. It would take 14 years just to get out there."

While many continue to debate the details of America's approach to space research, it is clear that we are committed to exploring the solar system. With the *Mariner Mark II* spacecraft, NASA has a cost-effective tool at hand for continuing with the latest phase of space exploration. The *CRAF* and *Cassini* projects may be just the first in a series of new and ambitious expeditions to uncover the secrets of the outer solar system, one that will carry the legacy of *Voyager* into the 21st century. ☐

Robert G. Nichols is a freelance science writer. His last article, "From Footprints to Foothold" (July 1989), won the Award of Excellence from the Air/Space Writer's Association.

MAGELLAN'S First Views of Venus

First-look radar images from Magellan show a surprising amount of geological activity.

by Robert Burnham

After a smooth flight — and a rocky checkout period in Venus orbit — the Magellan probe was beginning to make regular mapping passes as ASTRONOMY went to press. Before the craft lost contact with Earth on August 16 (the first of two times this occurred in less than a week), it had completed two orbits during which flight controllers tested the mapping radar. The pictures here are images from the tests.

"I was very pleased to get such useful and interesting images out of the radar test," marvels Stephen Saunders, Magellan's project scientist. "This has been a crack in the door. We're looking down on Venus and seeing things never seen before."

Photo A shows where the imaged region lies. Beta Regio is a broad volcanic upland that some planetary geologists think may be intermittently active. Photo B is a radar image made with the 1,000-foot Arecibo radio telescope and shows details as small as a mile across. The rectangular box marks the location of the new Magellan image (photo C).

The Magellan swath, measuring 12 by 90 miles, shows several distinct types of terrain. At the top are many roughly parallel mountains and valleys. "This looks like much of Nevada," says Saunders. "And it represents where the crust has been pulled apart." (Photo D shows a closeup.)

In the middle of the swath lies a region with crisscross structure. Called tesserae, from the Latin word for tile, these regions are relatively

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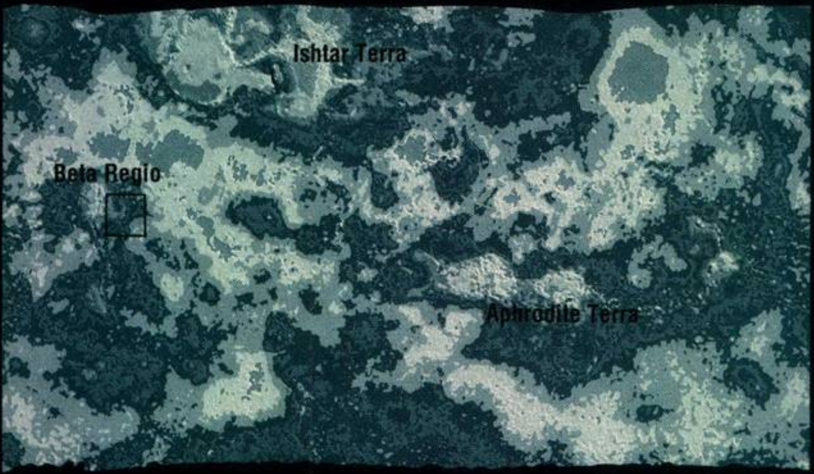

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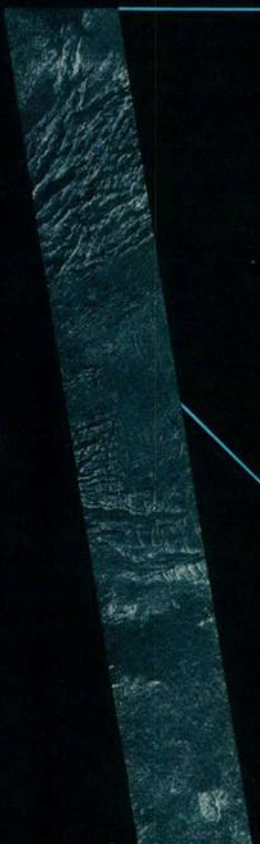
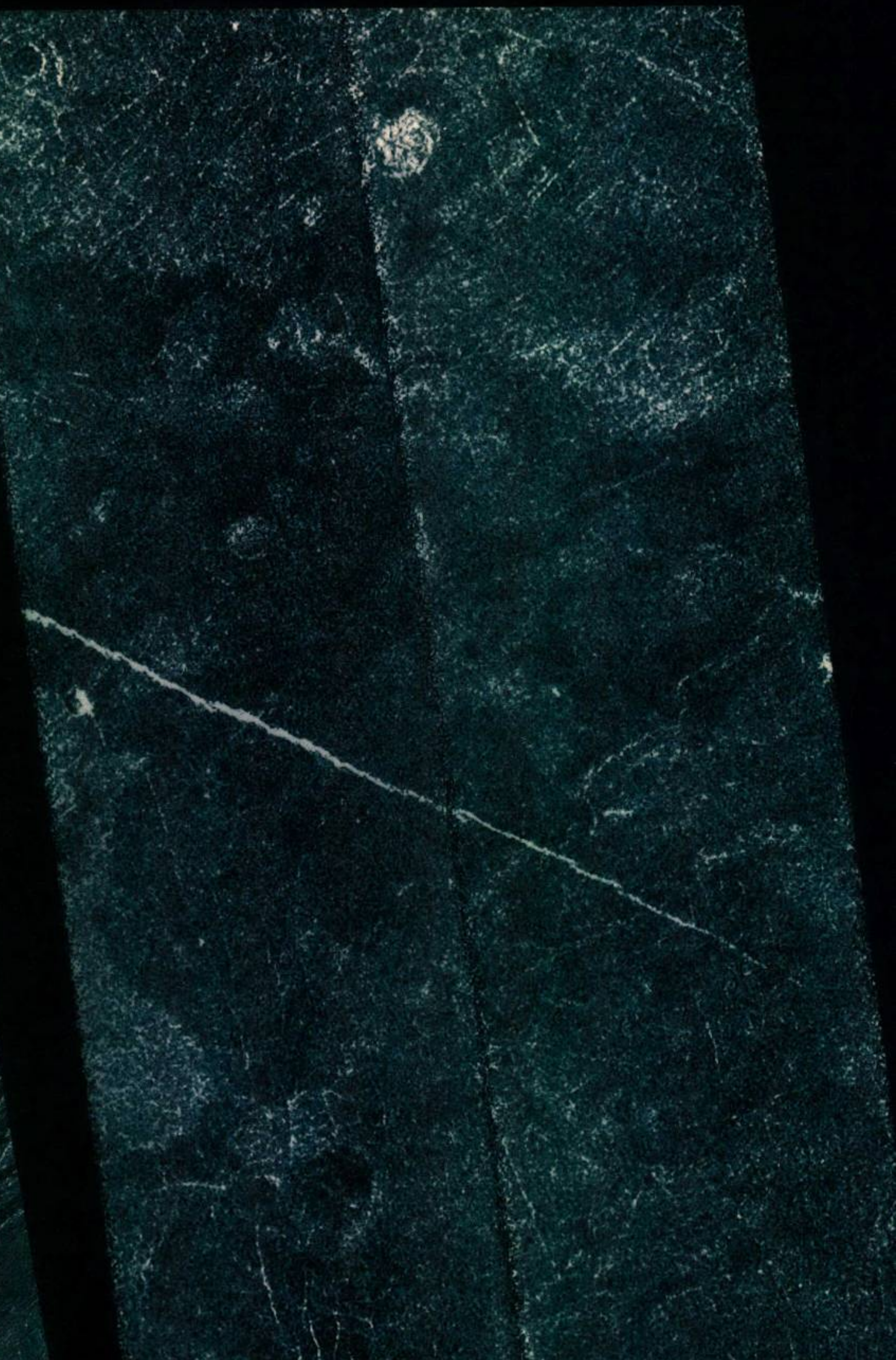


common on Venus but have no counterpart on Earth. Geologists think they are created by intensive local fracturing. The bottom of the swath shows lava flows of varying ages, with brighter areas being both younger and rougher in texture.

The region in photo E lies south of the others and shows mainly more lava flows. But the bright line cutting across the image marks the track of a crack or fissure. The round multi-ring features at top left and right are probably collapsed volcanic vents.

"What surprises me the most," Saunders remarks, "is that the fracturing, faulting, and lava eruptions that we saw before at coarser scales continue right down to the 400-foot resolution of Magellan's images.

"That's new," he says. "And it's significant. □



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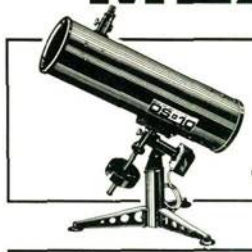

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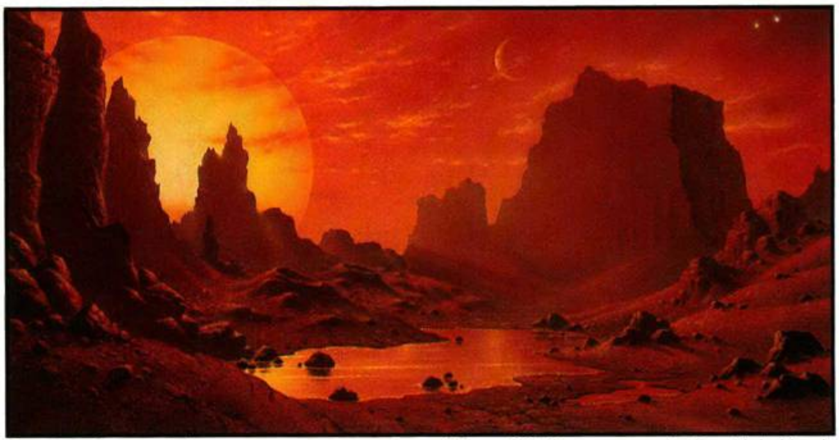

Proxima Centauri-the nearest star *edition of 950* *by David A. Hardy*

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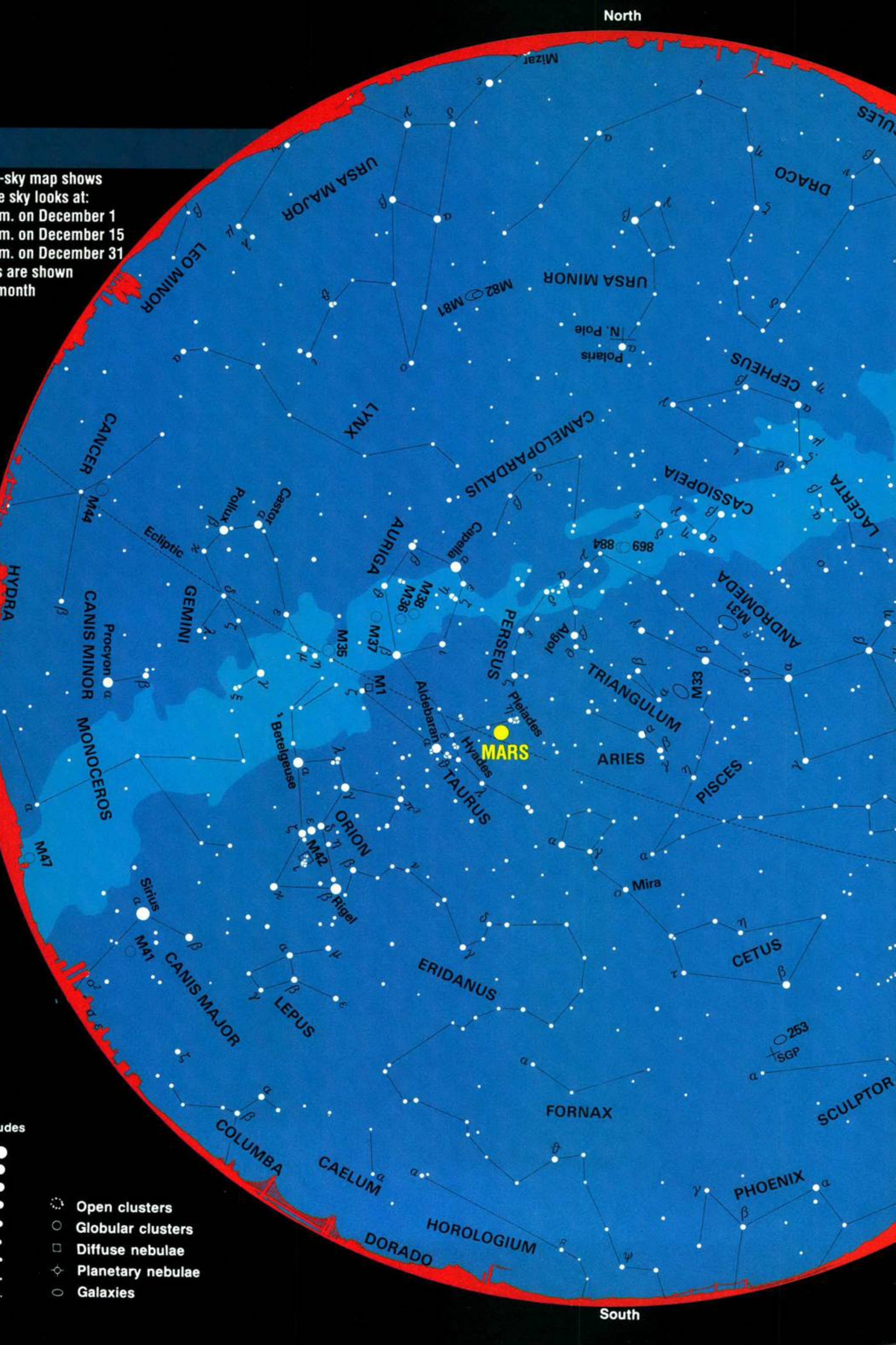
The all-sky map shows
how the sky looks at:
9:30 p.m. on December 1
8:30 p.m. on December 15
7:30 p.m. on December 31
Planets are shown
at midmonth


North
East
South
Mizar
URSA MAJOR
LEO MINOR
DRACO
URSA MINOR
M82 M81
N. Pole
Polaris
CEPHEUS
LYNX
CAMELOPARDALIS
CANCER
M44
CASSIOPEIA
LACERTA
Pollux
Castor
Ecliptic
AURIGA
Capella
869 884
HYDRA
CANIS MINOR
GEMINI
M38
M36
M37
M35
PERSEUS
Algol
ANDROMEDA
M31
Procyon
M1
TRIANGULUM
M33
Pleiades
Aldebaran
Hyades
MARS
ARIES
Betelgeuse
MONOCEROS
TAURUS
PISCES
ORION
M42
M47
Mira
Sirius
Rigel
M41
CANIS MAJOR
ERIDANUS
CETUS
LEPUS
253
SGP
SCULPTOR
FORNAX
COLUMBA
CAELUM
PHOENIX
HOROLOGIUM
DORADO

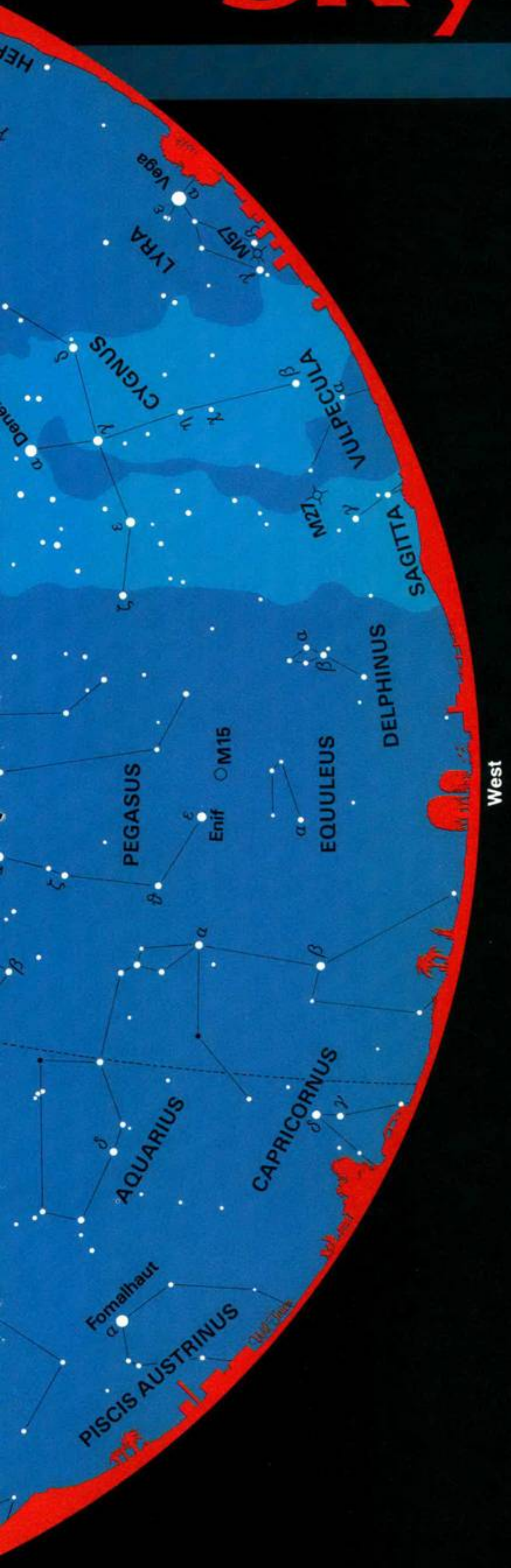
Magnitudes

Sirius	●
0.0	●
0.8	●
1.6	●
2.4	●
3.2	•
4.0	•
4.8	·
5.6	·

⁚	Open clusters
○	Globular clusters
□	Diffuse nebulae
✧	Planetary nebulae
⬭	Galaxies

Sky Almanac

December 1990



MARS BRIGHT IN THE EVENING

The Red Planet is conspicuous in the eastern evening sky throughout December. Naked-eye observers can follow the planet's progress as it passes the Pleiades star cluster around the middle of the month. Meanwhile, telescopic observers can scrutinize surface markings on the largest disk Mars will present for the rest of the century.

GEMINIDS PEAK DECEMBER 13/14

The moonless skies of mid-December will be filled with scores of bright yellow and white streaks as the Geminid meteor shower comes to a peak. Expect to see 60 or more meteors an hour on the night of December 13/14 and 20 to 30 an hour the night before and after.

A BLUE MOON FOR DECEMBER

For the first time in two-and-a-half years, two Full Moons occur in the same calendar month. The first of these Full Moons appears on the night of December 1/2, while the second — referred to as a "Blue Moon" — arrives on New Year's Eve.

Calender of Events

1 The Moon passes 3° north of Mars, 6 p.m. EST

2 Full Moon is at 2:50 a.m. EST
The Moon is at perigee (221,535 miles from Earth), 5:50 a.m. EST

5 Asteroid Psyche is at opposition

6 Mercury is at greatest eastern elongation (21°)
The Moon passes 2° south of Jupiter, 11 a.m. EST

8 Last Quarter Moon is at 9:04 p.m. EST

13 Geminid meteor shower peaks

15 The Moon passes 0.7° north of Antares, 4 p.m. EST
The Moon is at apogee (252,640 miles from Earth), 10:33 p.m. EST

16 New Moon is at 11:22 p.m. EST

18 Mercury passes 1.4° north of Venus, 6 p.m. EST

19 The Moon passes 0.2° south of Saturn, 10 a.m. EST

21 Winter solstice is at 10:07 p.m. EST

22 Ursid meteor shower peaks

24 Mercury is in inferior conjunction
First Quarter Moon is at 10:16 p.m. EST

28 The Moon passes 2° north of Mars, 8 p.m. EST

30 The Moon is at perigee (222,297 miles from Earth), 6:50 p.m. EST

31 Uranus is in conjunction with the Sun
Full Moon is at 1:35 p.m. EST

THE YEAR'S BEST METEOR SHOWER

This is the season to watch meteors. The Geminid meteor shower, which peaks this year during the night of December 13/14, is currently the richest and most reliable shower of the year. You can expect to see sixty or more meteors per hour that night and one-half to one-third that number the night before and after if you observe from a dark-sky site. Geminid meteors are usually bright, white or yellow in color, and travel at medium speeds.

The excellent prospects for this year's shower are brought to us in part by the absence of the Moon. At the peak of the Geminids, the Moon is a thin crescent that rises around 5 a.m. local time. And because the Geminid shower is one of the few showers that produces a large number of meteors before midnight, you don't have to wait until the coldest part of the night to go outside. However, any part of the night can be cold in December, so be sure to dress warmly, take along some hot coffee, tea, or cocoa to drink, and get up to move around occasionally so you don't get overly chilled.

MARS REMAINS BRIGHT

As the sky grows dark in the evening, you'll see a bright ruddy object in the east. Because it is so brilliant and noticeably orange-red in color, people who rarely look at the sky are apt to stare at it, wondering what it might be. It is the most familiar and mysterious of worlds, a place to which human beings will almost certainly go one day, the Red Planet Mars.

At the beginning of December, Mars is just four days past opposition, when it lay opposite the Sun in our sky. Now Earth is speeding on in its faster orbit around the Sun and quickly leaving Mars behind. But the Red Planet is still relatively nearby — roughly 49 million miles from us when the month begins and 63 million miles away when the month ends — and thus appears bright.

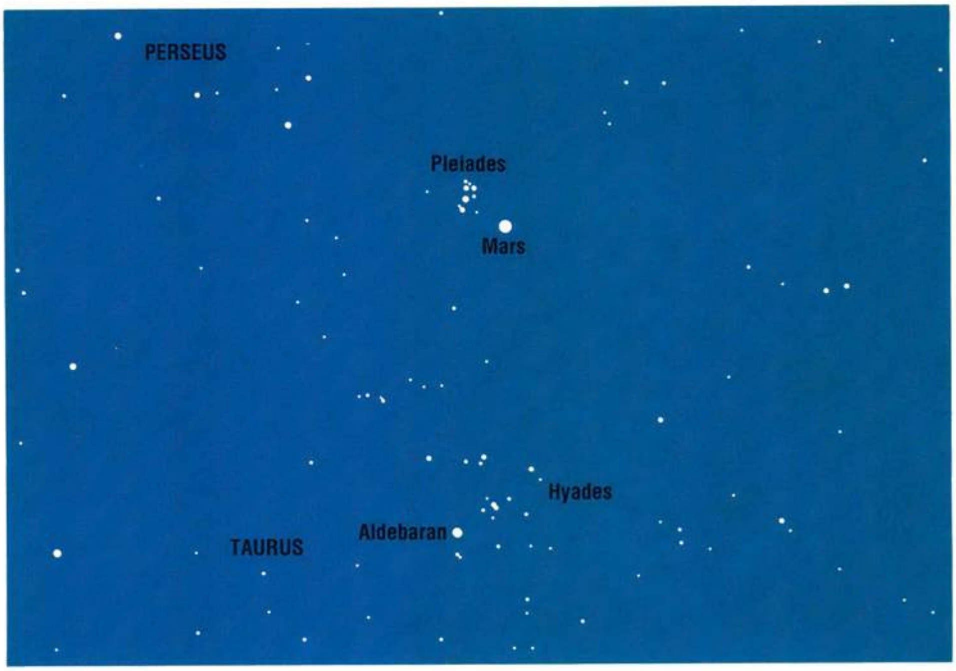
As the planet recedes during December, it grows dimmer in our sky. It was brightest at opposition on November 27, when it shone at magnitude –2.0. When December begins, the blazing Red Planet still outshines all the stars. By the end of the month, however, Mars has faded by a full magnitude and appears much less conspicuous.

THE GEMINID METEOR SHOWER peaks this year on the night of December 13/14, when the Moon is out of the sky. Photo of the 1982 Geminid shower by Michael Searle.

A COLORFUL FULL MOON

There are two Full Moons this month, the first on the night of December 1/2 and the second on the evening of December 31. Every Full Moon has a name, which coincides with the month of the year, and December's Full Moon is called the Moon Before Yule or the Long Night Moon. However, two Full Moons in a single month pose a problem: What is the second one called?

At least in recent years, the second Full Moon in a month has been called a Blue Moon. I don't know when this tradition began, but some people think it dates



MARS AND THE PLEIADES form a pretty pair in mid-December, when the Red Planet passes 2° from the star cluster. Look due east as evening twilight fades to locate the pair.

from Egyptian times. J. Hugh Pruett of the University of Oregon wrote an article in 1946 in which he attempted to trace the origin of the expression "once in a Blue Moon." He mentioned a 1937 Maine Farmers' Almanac, which gave the names for each month's Full Moon. Then he asserted, "But seven times in 19 years there were — and still are — 13 Full Moons in a year. This gives 11 months with one Full Moon each and one with two. The second in a month, so I interpret it, was called a Blue Moon."

Blue Moon is a quaint name, but it's an exceedingly rare occurrence to see a Moon that is actually blue in color. Highly unusual atmospheric conditions are needed to produce one. On the other hand, the name Long Night Moon describes both Full Moons this month very well. They are the nearest Full Moons to the December solstice, which means that the nights on which we see them are especially long.

DECEMBER'S PLANETS

Venus has been hiding in the Sun's glare for nearly three months now, but it returns to the southwestern evening sky during the second half of December. No other planet would be visible so low in the sky, but Venus is very brilliant at magnitude –3.9.

The innermost planet, Mercury, lies low in the southwest after sunset during the first half of December. Unfortunately, this is an unfavorable apparition for the elusive planet and you'll be hard-pressed to find it. It reaches greatest elongation on December 6, when it is 21° east of the setting Sun. Even though the planet shines at magnitude –0.4 then, it is hard to see because it lies only 5° above the horizon forty-five minutes after sunset.

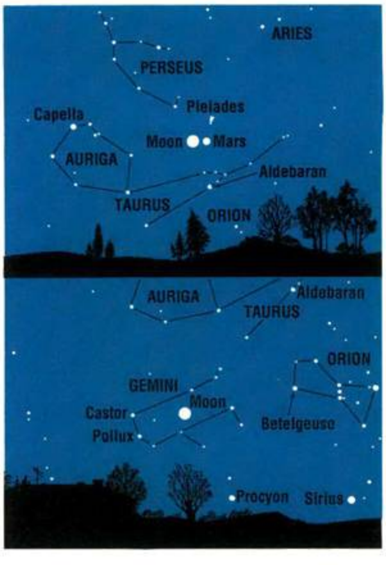
Saturn appears low in the southwest at sunset, where it shines at magnitude 0.6. It will soon drop into the Sun's glare along with the constellation it resides in, Sagittarius. As Martha Evans Martin wrote in her 1912 book, *The Ways of the Planets,* Saturn "sometimes seems as red as Mercury, and sometimes even twinkles a little in a sort of farewell gaiety as it backs away from us into the rays of the dazzling Sun and finally disappears for a time from the evening sky."

Bright, fiery, and unmistakable, Mars is a wonderful sight this month. It lies in the east as the Sun goes down and spends the evening ascending toward the zenith. Mars is exceedingly bright at magnitude –2.0 in early December and, although only 40 percent as bright, still conspicuous at magnitude –1.0 at month's end.

Jupiter, the king of planets, rises over the east-northeastern horizon in mid-evening. At magnitude –2.4, Jupiter is far brighter than any star in the sky. It is so bright, in fact, that it puts even Mars to shame.

Jupiter will soon appear opposite the Sun from Earth, a configuration called opposition. Like the other outer planets, with the exception of Mars, Jupiter generally comes to opposition once a year as Earth orbits each year around the Sun. For Jupiter, which requires twelve earthly years to complete a single orbit, each opposition takes place

DECEMBER'S TWO FULL MOONS give us the first "Blue Moon" since May 1988. The Full Moon on the night of December 1/2 lies in Taurus next to Mars (below), while the Full Moon on December 31 lies in Gemini (bottom).



about a month later than it did the year before. In other words, we take a year to travel around the Sun, then require an extra month to catch up to Jupiter again. Last year's opposition of Jupiter was in December, and thus there is no opposition of this planet in 1990. We'll pass between Jupiter and the Sun at the end of January.

THE STARRY SKY

On frosty nights in December, as colored Christmas lights illuminate our homes and hearts below, the sky above reminds us of another holiday tradition. It's the tradition of the star described in the Gospel according to St. Matthew, the legendary Star of Bethlehem.

For centuries, astronomers have been called upon to reveal the true identity of the Christmas star. Some have tried, while others have commented that the star probably wasn't a real celestial object. Many ancient cultures believed that stars heralded the birth of kings. Some Biblical scholars think that the Star of Bethlehem may have been used as a symbol of a religious experience.

On the other hand, astronomers have offered a variety of natural explanations for the Christmas star. They always start with the fact that, in today's numbering system, the birth of Jesus didn't occur in the year 1, as you might suppose. Instead, it probably happened between 11 and 4 B.C.

Some of the astronomical possibilities are pretty far-fetched. One suggests that the Christmas star might have been a sighting of the planet Uranus, which wasn't discovered until centuries later. Even at its brightest, Uranus is definitely an uninspiring sight, only marginally visible to the naked eye.

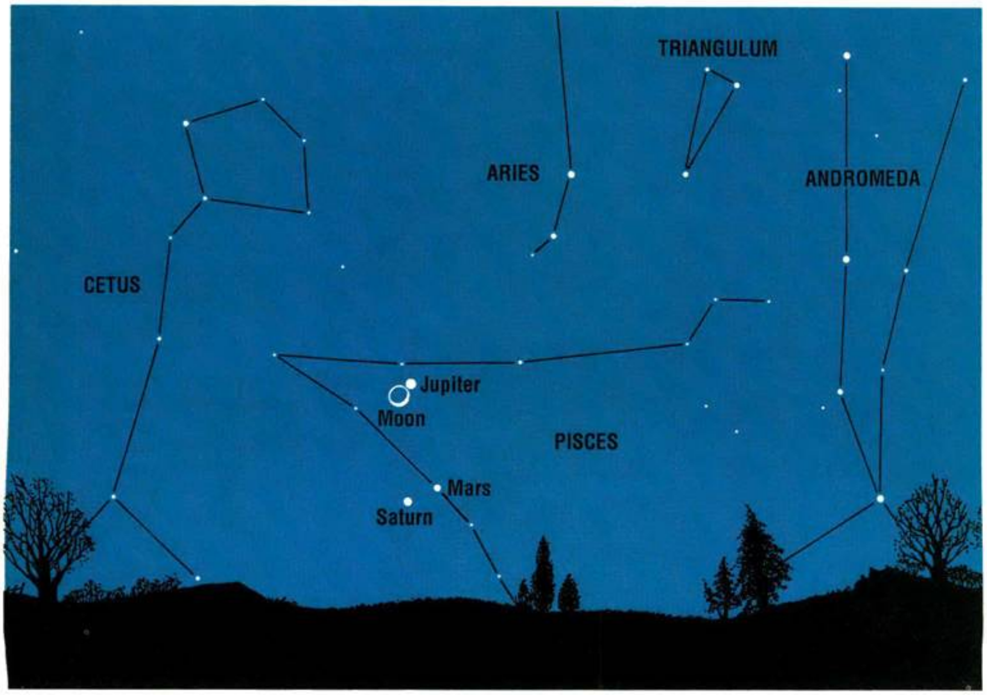
A bright comet has also been mentioned as a possible Christmas star. Comets in those days were called "hairy stars." A brilliant comet with a long tail might have been regarded as the "finger of God," pointing the way to a significant occurrence.

A triple conjunction of Jupiter and Saturn, which took place in 7 B.C., was made famous as a Christmas star possibility in the 19th century. This event took place in the constellation Pisces, which may have had significance to the Jews. And the following year, Mars joined Jupiter and Saturn in a celestial gathering that some people think could have been the Christmas star.

Or, the Star of Bethlehem may really have been a star, a nova observed in 5 B.C. and recorded by Chinese astronomers. A nova is a star that flares up suddenly in brightness. When one erupts, it can cause a formerly invisible star to burst into view — in short, to look like a new star.

What was the true identity of the Christmas star? We'll never know for certain, and indeed it doesn't really matter. The real significance of the Christmas star lies beyond the realm of the starry sky. □

A RARE GROUPING of Mars, Jupiter, and Saturn in the year 6 B.C. is one of many suggested astronomical explanations for the Christmas Star. On the evening of February 20, the three planets were joined by a thin crescent Moon.



Deborah Byrd is the creator, writer, and producer of "Star Date," an independently syndicated daily radio series on commercial and public radio.

Through the Eyepiece *by* Rick Shaffer

VIEWING THE RED PLANET

Mars reached opposition during the last week of November, so as December begins the planet is well-placed for telescopic viewing. Mars rises before the Sun sets and is easy to find in the east as the sky grows dark, but the best time to observe the Red Planet is when it is highest in the sky during the late evening hours.

For observers at 30° north latitude, Mars lies within 10° of the zenith when it crosses the meridian, so you'll be looking through almost the minimum amount of image-distorting air as possible. From more northerly latitudes, the planet appears lower in the sky, but it is still much higher than during typical apparitions.

Mars' high altitude certainly improves your chances of seeing lots of details on the Martian surface, but it will be for naught if your local seeing conditions are poor. Choose an observing site carefully. Avoid areas near concrete buildings, asphalt parking lots, or other objects that absorb the Sun's radiation during the day and then reradiate it at night. A grassy or snow-covered field or a hilltop overlooking a wooded area is ideal.

To locate the major features you'll be able to see on Mars, use the map and table of central meridian crossings at right. Your best view will be of features that lie within about 60° of the Martian central meridian. (For more information on observing Mars, see "Mars Shows Its Stuff" in the November issue.) You can make the dark markings appear more prominent by viewing the planet through an orange filter (Wratten 21 or 23A) or red filter (Wratten 25 or 29).

PLANETARY OBSERVING WITH CLYDE TOMBAUGH

The amount of detail you actually see on Mars, or any other planet for that matter, depends on many factors, including the seeing, your equipment, and your experience and skill as an observer. But it's amazing how much you *can* see under the right circumstances.

That point was brought home to me recently during a conversation with Clyde Tombaugh, who discovered Pluto sixty years ago and is a renowned planetary observer. Although Tombaugh owns many telescopes, his favorite is a 16-inch f/10 planetary scope he built in the early 1960s.

With this telescope and the excellent skies around Las Cruces, New Mexico, Tombaugh has seen the spokes in Saturn's rings on several occasions. He told me that he had spotted the spokes during one recent period of great seeing, and "I called my son-in-law on the phone in the middle of the night so he could see them too. But I didn't tell him what I'd seen, just to take a good long look. He saw them just where I did, at two o'clock and nine o'clock."

On other occasions, Clyde has seen detail on the Jovian moon Io and the white cloud that occasionally forms over the Martian volcano, Olympus Mons.

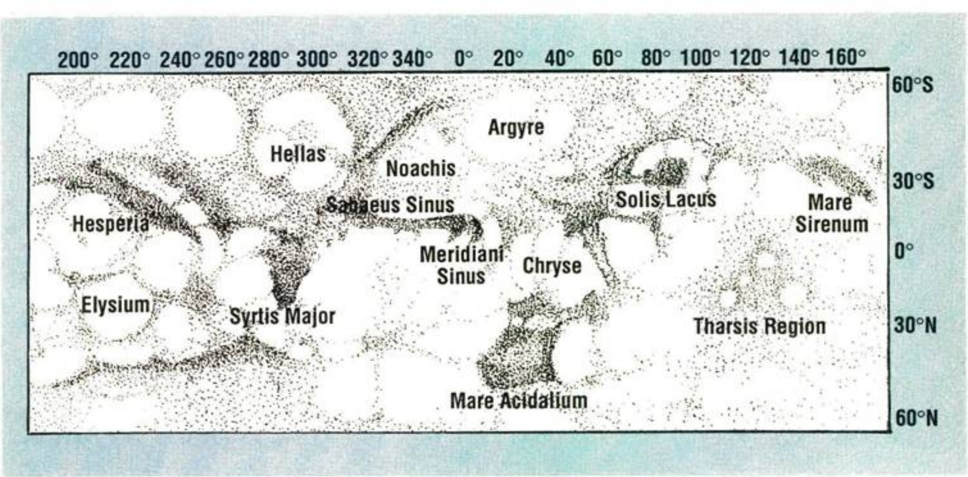
This goes to show the amazing amount of detail that can be seen when the conditions are right. But you won't see it if you look only on a casual basis. You have to put in your time. Doing so increases the probability that you'll be at the eyepiece when that moment of exquisite seeing occurs. But just as important, putting in time at the eyepiece guarantees that your eye-brain

MARTIAN CENTRAL MERIDIANS

Date	Central Meridian
December 1	185°
December 4	159°
December 7	133°
December 10	106°
December 13	79°
December 16	53°
December 19	26°
December 22	359°
December 25	332°
December 28	304°
December 31	277°

Central meridians are given for 11 p.m. EST (10 p.m. CST, 9 p.m. MST, and 8 p.m. PST). To find the central meridian at other dates and times, subtract 9.1° for each day after a tabulated date and add 14.6° for each hour after the tabulated time.

MARTIAN SURFACE FEATURES should be prominent this month because the Red Planet looms large in our sky. Use the surface map and table of meridian crossings to determine what features are visible at any given time.



MUTUAL EVENTS OF THE GALILEAN SATELLITES

Begin Date	End Time	Time	Event	Type of Event	Light Loss	Distance
Dec. 4	11h48m	12h00m	Europa Occults Ganymede	Annular	23%	9
Dec. 11	15h10m	15h24m	Europa Occults Ganymede	Annular	23%	9
Dec. 18	15h12m	15h15m	Europa Eclipses Ganymede	Partial	0%	11
Dec. 18	18h33m	18h48m	Europa Occults Ganymede	Annular	23%	9
Dec. 25	18h53m	19h04m	Europa Eclipses Ganymede	Partial	3%	11
Dec. 25	21h59m	22h16m	Europa Occults Ganymede	Annular	23%	9
Dec. 28	19h20m	20h22m	Europa Occults Io	Partial	3%	4

Begin Time: Universal time at beginning of event. (Subtract 5 hours to convert to EST, 6 hours for CST, 7 hours for MST, and 8 hours for PST.) **End Time:** Universal time at end of event. **Event:** The nature of the event and the satellites involved. **Type of Event:** Whether the event is partial, total, or annular. **Light Loss:** For eclipses — the percent of light lost by the eclipsed satellite at midevent; For occultations — the percent of light lost from the combined light of both satellites at midevent. **Distance:** The apparent distance of the satellite from Jupiter's center expressed in Jovian equatorial radii.

combination will be trained to take full advantage of the great seeing when it does occur.

KEEP AN EYE ON JUPITER

While Mars shrinks in size this month following its opposition in November, Jupiter is growing in size as it approaches opposition in January. The giant planet measures 43" across in mid-December, far larger than any other planet, and it is high in the sky during the hours after midnight. The large size and high altitude mean that details in the Jovian atmosphere will be easier to see than they have been for the past several months.

And there should be plenty of details to observe. It now appears that the South Equatorial Belt (SEB), which faded to near invisibility during Jupiter's previous apparition, is on its way back. The SEB was returning to prominence rapidly in mid-September, according to Jose Olivarez, Jupiter Recorder for the Association of Lunar and Planetary Observers. Olivarez predicted that both components of the SEB would be considerably rejuvenated by December. In addition, the Great Red Spot appears to be fading and should be quite a bit paler in December than it was before last summer's conjunction.

OBSERVE THE MANY SPLENDORS of Jupiter's Galilean satellites this month. The pace of mutual occultations and eclipses quickens in December (above), while phenomena of the satellites with Jupiter continue unabated (below).

SATELLITE PHENOMENA

Date	Event	Time
	IO	
Dec. 15	Eclipse begins	6h05m
	Occultation ends	9h22m
Dec. 23	Shadow enters	5h17m
	Transit begins	6h06m
	Shadow leaves	7h33m
	Transit ends	8h23m
Dec. 30	Shadow enters	7h10m
	Transit begins	7h51m
	Shadow leaves	9h27m
	Transit ends	10h08m
	EUROPA	
Dec. 14	Shadow enters	5h22m
	Transit begins	7h21m
	Shadow leaves	8h15m
	Transit ends	10h15m
Dec. 30	Eclipse begins	5h21m
	Occultation ends	9h36m
	GANYMEDE	
Dec. 12	Eclipse begins	3h49m
	Eclipse ends	7h24m
	Occultation begins	7h55m
	Occultation ends	11h32m

Times are given in universal time. Subtract 5 hours to convert to EST, 6 hours for CST, 7 hours for MST, and 8 hours for PST.

The Jovian atmosphere isn't the only area of interest to Jupiter observers. The pace of mutual occultations and eclipses among the planet's four Galilean satellites, which began last month, picks up in December. There are seven such events this month, six of them easy to observe if Jupiter is above the horizon in a dark sky at your location. (See the table above for a complete listing.) The one event that is virtually undetectable is the partial penumbral eclipse of Ganymede by Europa on December 18.

The best event for North American observers is the occultation of Ganymede by Europa on the morning of December 4. Europa's disk glides in front of Ganymede's disk beginning at 11h48m UT (6:48 a.m. EST, 3:48 a.m. PST), and leaves the disk 12 minutes later. At mid-occultation Europa's 1.0"-diameter disk lies entirely inside the 1.7"-diameter disk of Ganymede, and the combined light of the pair drops 23 percent below their normal, unocculted light.

You can also observe phenomena of the Galilean satellites with Jupiter — eclipses, transits, and occultations — during December. As the satellites orbit Jupiter, they pass both in front of and behind the planet. When a satellite passes in front, its shadow precedes it, so we see the shadow of the satellite crossing Jupiter before the disk transits. When a satellite goes behind Jupiter, we see it eclipsed by Jupiter's shadow before Jupiter occults the satellite's disk. (The best of the satellite phenomena for North American observers are given in the table at left.)

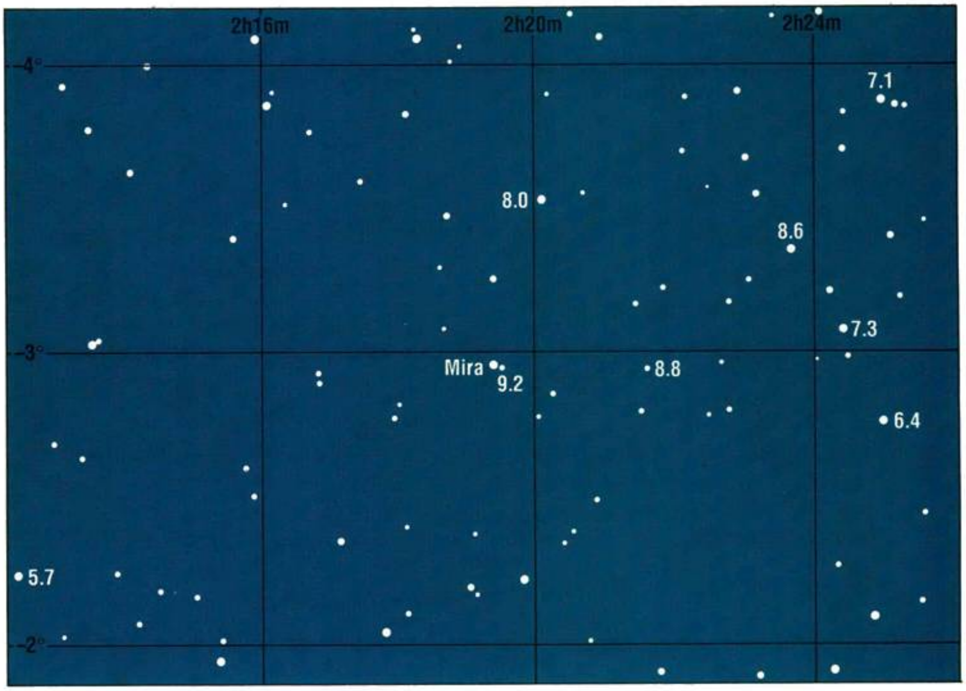
MIRA GROWS FAINTER AND REDDER

Two months ago I devoted considerable space to a considerable variable star — Mira, the prototypical pulsating variable. Mira should have reached a maximum brightness of around 3rd or 4th magnitude in late September or early October. Now it is well along on its way to a minimum magnitude of about 9.5, which it should reach sometime this spring. If you have access to a 12-inch or larger telescope, you should be able to see Mira grow redder as its brightness fades.

But a telescope of almost any size will let you make visual estimates of the variable's magnitude as it fades over the next several months. First, use the chart at right to locate Mira and to identify stars of fixed magnitude that you can use to compare against Mira's brightness. Then pick a comparison star whose brightness seems to be close to Mira's.

Alternately look at Mira and the comparison star. If the comparison star is brighter than Mira, record its magnitude and pick another star that's a bit dimmer. If this second comparison star still appears brighter than Mira, erase the recorded magnitude of the first star and record the new comparison star's brightness. (If the first comparison star was fainter than Mira, pick a slightly brighter star for your second comparison and follow the same procedure.)

Use this technique to bracket Mira's brightness between that of two comparison stars. If Mira appears to be halfway between the brightnesses of your two comparison stars, the average of the comparison stars' magnitudes is the magnitude of Mira. If Mira seems closer in brightness to one of the comparison stars than the other, estimate its magnitude from how close it is to that star's magnitude.



MIRA SLOWLY GROWS DIMMER over the course of the next several months. As it does so, you can measure the variable star's magnitude by comparing it with the magnitudes of nearby stars.

TELESCOPIC PLANETS

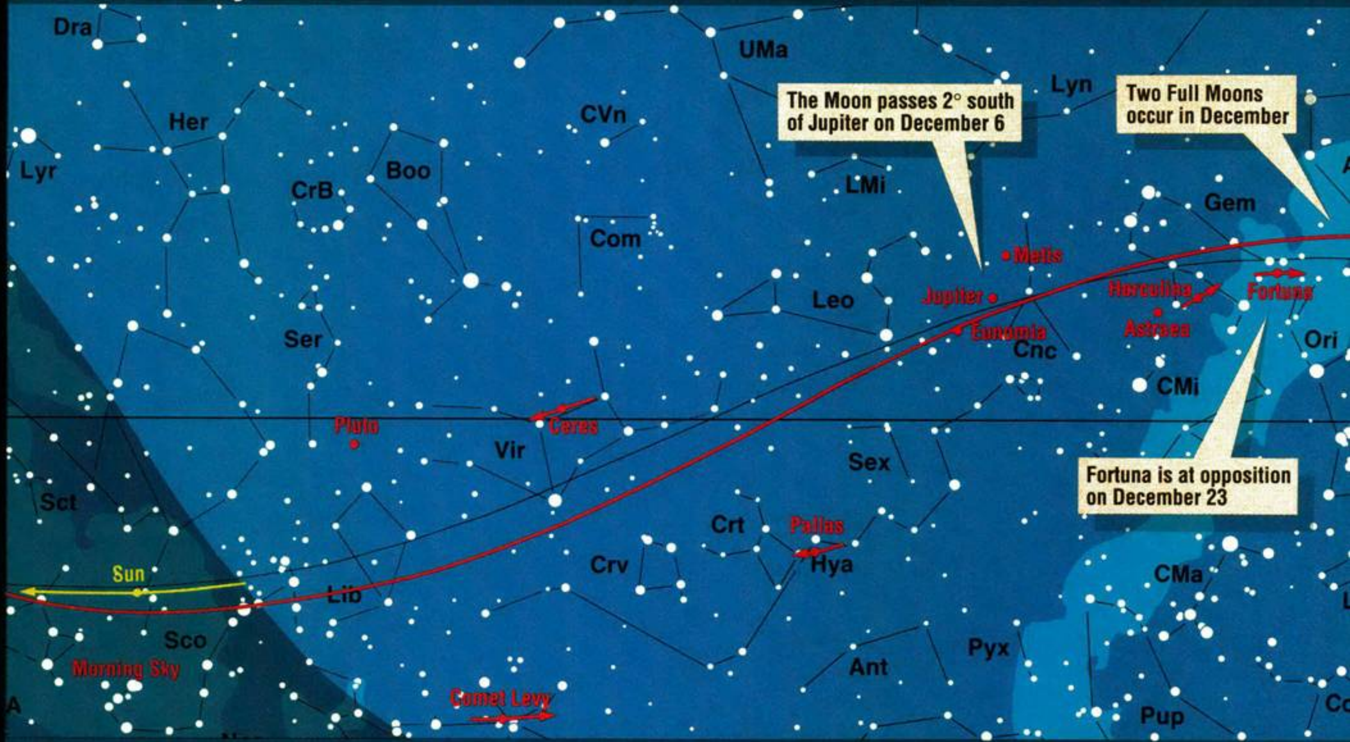
Mercury lies 21° east of the Sun on December 6, the date of its greatest elongation. Unfortunately, the planet is well south of the ecliptic and thus remains low in the southwest sky throughout this evening apparition. Your best chance to observe Mercury comes on the 6th, when it lies 5° above the horizon forty-five minutes after sunset. The –0.4-magnitude planet shows a disk 6.6" in diameter that is 63-percent illuminated.

After three months of invisibility behind the Sun, Venus returns to view in the evening sky in mid-December. The telescopic appearance of Venus changes very slowly at this point in its apparition, so you won't miss anything if you observe it once every week or two. Venus appears 10.2" across and 97-percent lit on the 31st, when it shines at magnitude –3.9.

As Venus returns to the evening sky, Saturn leaves it. Although the ringed planet remains in view until the end of the month, you'll be better off observing it in early December. On the 1st, Saturn has a 15.5"-diameter disk surrounded by a beautiful ring system spanning 35". Saturn's neighbors in Sagittarius, Uranus and Neptune, lie even closer to the horizon than Saturn does, and you'll be hard-pressed to see them as anything more than shimmering disks. □

Rick Shaffer is a technical group leader at the Jet Propulsion Laboratory in Pasadena, California. He is also a telescope and Frisbee nut, owning more than a few of both.

The Solar System   December 1990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Cnc
Astraea
Ser
Ori
CMi
Pluto
Ceres
Vir
Sex
Sct
Crt
Pallas
Hya
Crv
CMa
Sun
Lib
Sco
Morning Sky
Ant
Pyx
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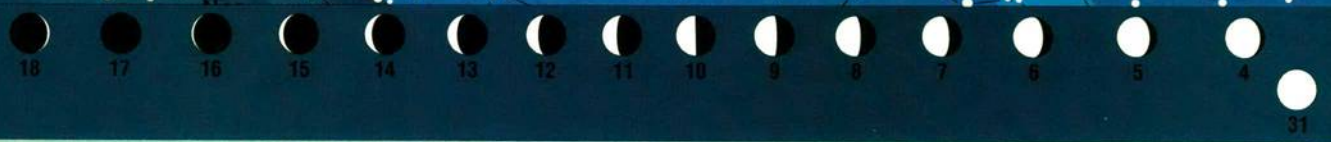
Comet Levy

The Moon passes 2° south of Jupiter on December 6

Two Full Moons occur in December

Fortuna is at opposition on December 23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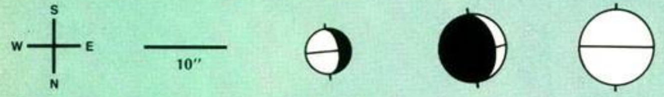
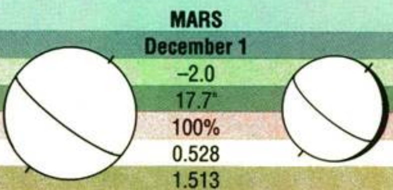
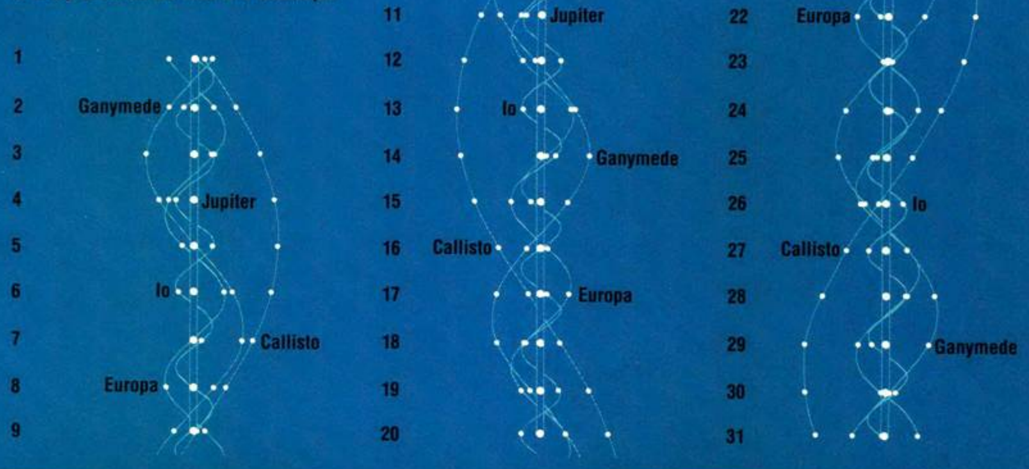


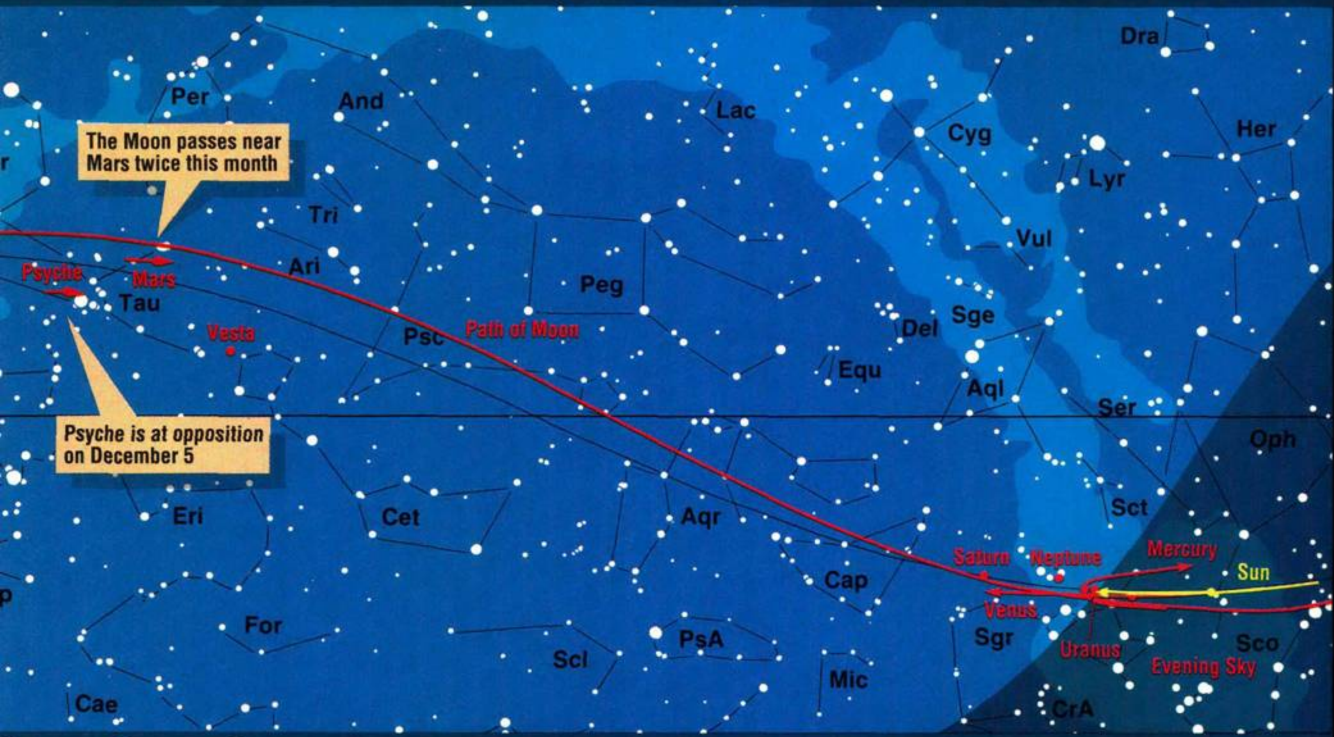


Planet	MERCURY	MERCURY	VENUS	MARS	MARS
Date	December 1	December 31	December 15	December 1	December 31
Magnitude	–0.4	+1.4	–3.9	–2.0	–1.0
Angular Size	6.0"	9.2"	10.0"	17.7"	13.9"
Illumination	75%	17%	98%	100%	95%
Distance (AU) from Earth	1.125	0.731	1.672	0.528	0.671
Distance (AU) from Sun	0.397	0.331	0.728	1.513	1.552
Right Ascension (2000.0)	17h54.9m	17h38.6m	18h15.4m	4h08.0m	3h40.2m
Declination (2000.0)	–25°52'	–20°12'	–24°10'	22°34'	21°58'

Jupiter's Moons

Dots display positions of Galilean satellites at 5 UT on date shown. South is at top to match the view in a telescope.




Per
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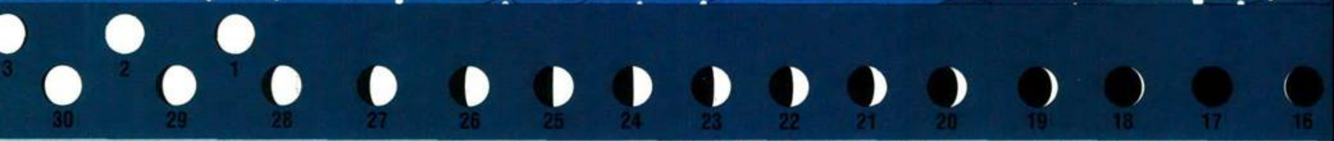
Sct
Aqr
Saturn
Neptune
Mercury
Sun
Cap
Venus
For
Sgr
Scl
PsA
Uranus
Sco
Evening Sky
Mic
Cae
CrA

The Moon passes near Mars twice this month

Psyche is at opposition on December 5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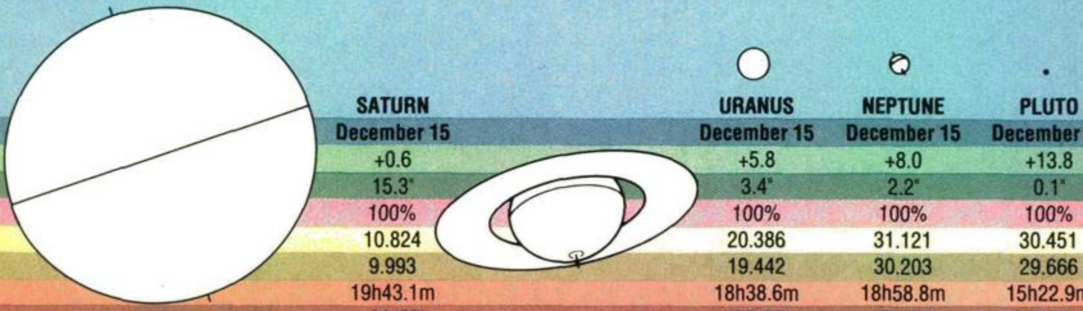
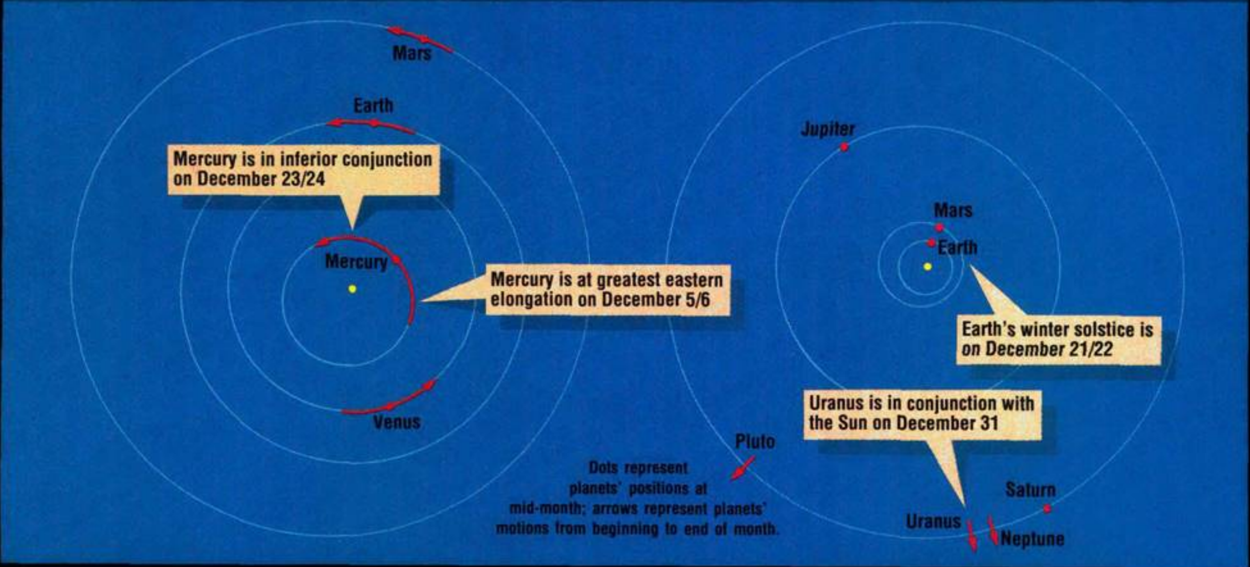


JUPITER December 15	SATURN December 15	URANUS December 15	NEPTUNE December 15	PLUTO December 15
−2.4	+0.6	+5.8	+8.0	+13.8
42.9"	15.3"	3.4"	2.2"	0.1"
99%	100%	100%	100%	100%
4.595	10.824	20.386	31.121	30.451
5.276	9.993	19.442	30.203	29.666
9h04.0m	19h43.1m	18h38.6m	18h58.8m	15h22.9m
17°25'	−21°27'	−23°28'	−21°57'	−3°11'

The Planets in Their Orbits


Mars
Earth
Mercury
Venus
Jupiter
Mars
Earth
Pluto
Saturn
Uranus
Neptune

Mercury is in inferior conjunction on December 23/24

Mercury is at greatest eastern elongation on December 5/6

Earth's winter solstice is on December 21/22

Uranus is in conjunction with the Sun on December 31

Dots represent planets' positions at mid-month; arrows represent planets' motions from beginning to end of month.

THE MOON

How to Find a Lunar Volcano

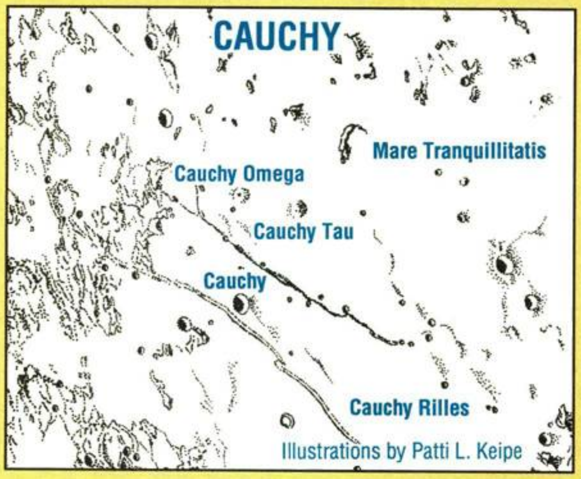
Moon volcanos are small and hard to find — and fascinating because they show the Moon at its most Earthlike.

by Michael T. Kitt

Does the Moon have volcanos? In the pre-Space Age era, this question was easy to answer: Of course the Moon has volcanos — look at all those craters! But by the 1960s, planetary scientists had determined that the overwhelming majority of lunar craters were made by meteorite impact, and the idea of lunar volcanos fell into deep eclipse.

Nonetheless, one type of lunar volcanic activity certainly *has* occurred: floods of lava. The maria — the dark lunar "seas" that cover a fifth of the entire Moon — are vast sheets of once-molten basalt. About 3.8 billion years ago, they oozed out to fill the gaping basins created by enormous impacts.

But what about volcanic activity at smaller scales? Are there lunar equivalents to Mauna Loa, Mt. Etna, or Mount St. Helens? The answer is yes, but it's easy to see why these features get overlooked — they're small, few in number, and not easily seen.



Illustrations by Patti L. Keipe

Twenty-one years ago lunar samples returned by the *Apollo* program showed that nearly all lunar lava was originally so runny that it flowed almost like water. In fact, the lunar lavas were so highly fluid that their final act was to pool over and completely cover the vents and fissures from which they emanated.

As a consequence, except for the vast, relatively unmarked maria, only a few volcanic structures are visible on the Moon. There are a small number of sinuous rilles (see "Looking for Lunar Fractures," February 1988), but these are merely conduits that carried molten lava from a volcanic vent out into the maria. If you really want to find a lunar volcano, you have to look for a lunar dome — a kind of low, rocky blister on the Moon's surface.

Most backyard astronomers have never seen a lunar dome, including many who regularly scan the Moon. To understand why, consider that a large dome may be only 200 to 500 feet high and a dozen miles in diameter. Most domes are just very gentle hills, with slopes of only a few degrees. In fact, if you were an astronaut standing at the base of one, you might not even know it was there. And if you're an amateur astronomer viewing the dome in a small telescope, you need to view it under precisely the right conditions if you are to see it at all.

The typical lunar dome becomes visible when the grazing light of dawn or sunset makes every little bump stand out boldly. This means that you must go "dome hunting" in whatever area the lunar terminator is moving across. Moreover, under these conditions domes appear only briefly; some are visible for just a couple of hours when the terminator passes them. Fortunately, the largest domes tend to have steeper slopes and are easier to pick out. But even the largest are visible for only a day or two after local sunrise or before sunset.

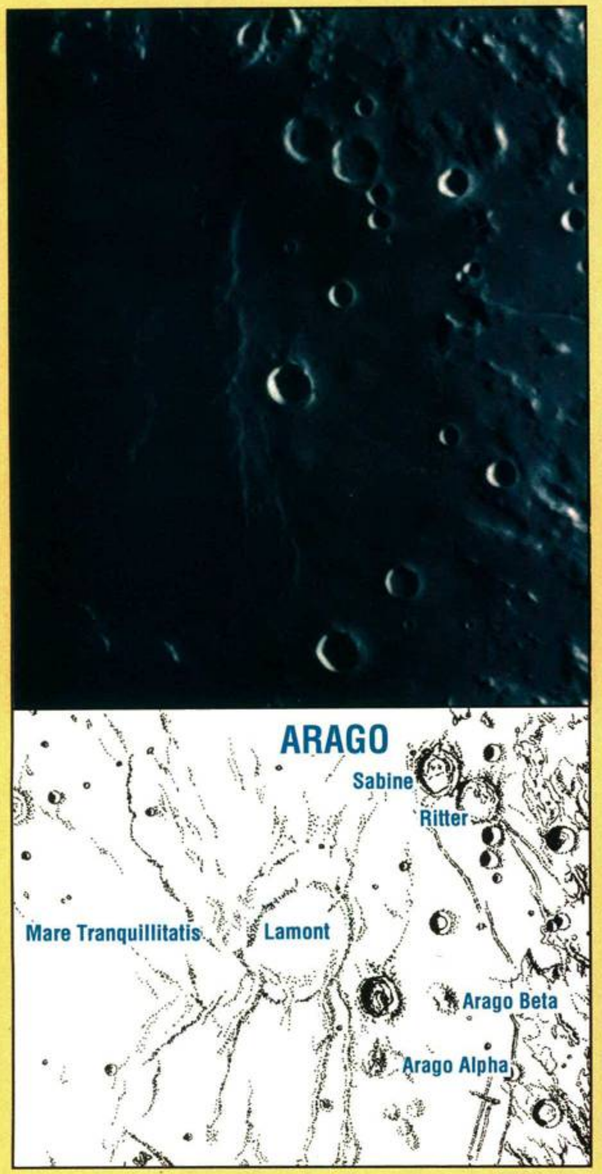
Where should you look? If you had to scrutinize the entire lunar terminator inch-by-inch every night as it crept across the Moon, you'd abandon domes in no time at all! Luckily, finding domes is simplified by the fact that they are not scattered at random, but tend to occur in clusters, usually near the edges of the maria. Scientists think this indicates that domes are low-energy volcanic outbursts that occurred late in the Moon's geologically active phase.

You can ignore the lunar highlands, the chaotic southern portion of the Moon that has been pounded by billions of years of impacts. Nor is there much point in checking the centers of the maria, where flow upon flow of lava has obliterated everything. Instead, examine the margins of the lunar seas, where the lava flowed thinnest. Many domes can also be found within craters located where the seas encroach on highland areas. Such craters were often flooded from the nearby maria, and geological conditions were suitable for making domes.

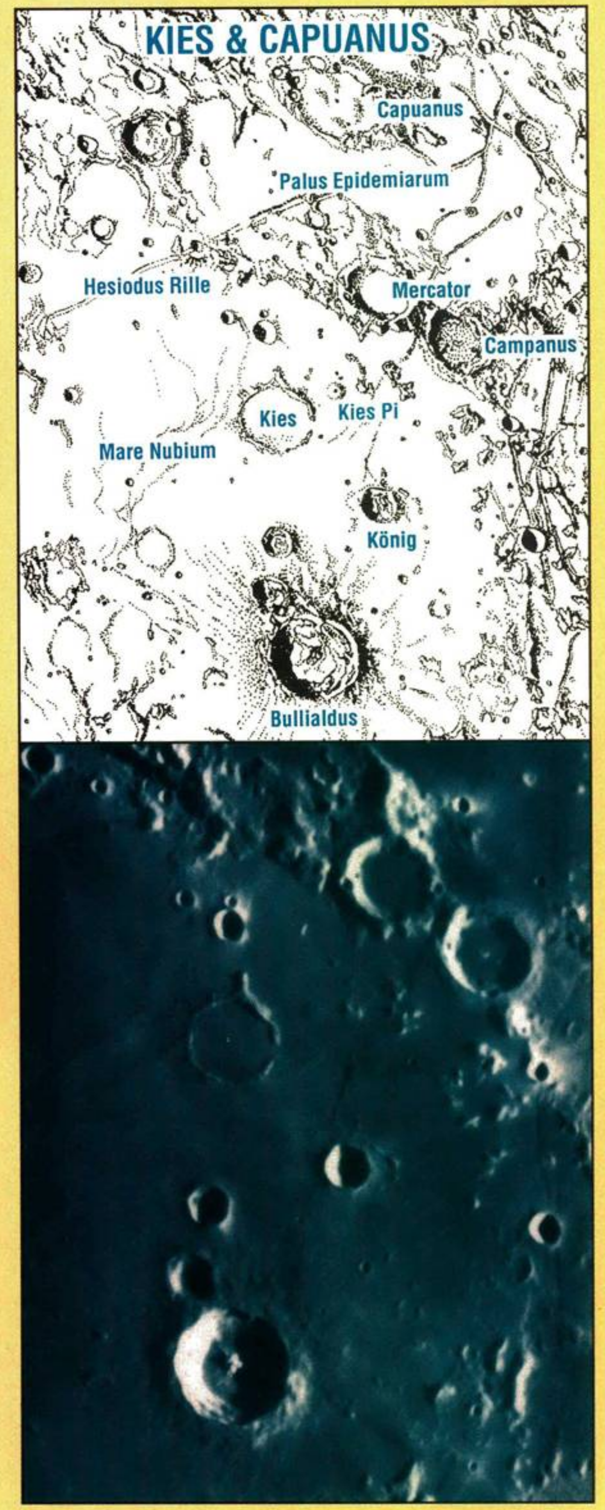
The most common type of lunar dome has the profile of a flattened lens. These are usually featureless, although many have a small, shallow, rimless crater at their summit, just like the caldera atop Kilauea in Hawaii. Other domes are steeper, more hill-like, and show some surface detail; these do not have summit pits. Low-relief domes most strongly resemble terrestrial shield volcanos like Mauna Loa and this is probably what they are. The other varieties of dome may represent lunar versions of terrestrial cinder cones or may simply be local uplifts caused by an injection of lava into an underground reservoir.

Your first good chance to observe a lunar dome comes five days after New Moon. Located on the eastern margin of Mare Tranquillitatis is the crater Cauchy, 8 miles in diameter. It is flanked to the northeast and southwest by thin faults running roughly parallel. (All directions refer to lunar east and west.) Immediately to the south of the southwest fault sit two domes side by

LATE AFTERNOON SUN shows details in western Mare Tranquillitatis, including volcanic domes near Arago. Most domes lie on the edges of the lunar "seas." Photo by Jean Dragesco; south is up in all maps and photos.


ARAGO
Sabine
Ritter
Mare Tranquillitatis
Lamont
Arago Beta
Arago Alpha

FLOODED BY LAVA, the ruined crater Kies lies in Mare Nubium; the small dome Kies Pi stands to the west (right) of it. Photo by Christian Arsidi.


KIES & CAPUANUS
Capuanus
Palus Epidemiarum
Hesiodus Rille
Mercator
Campanus
Kies
Kies Pi
Mare Nubium
König
Bullialdus

LUNAR DOME COUNTRY

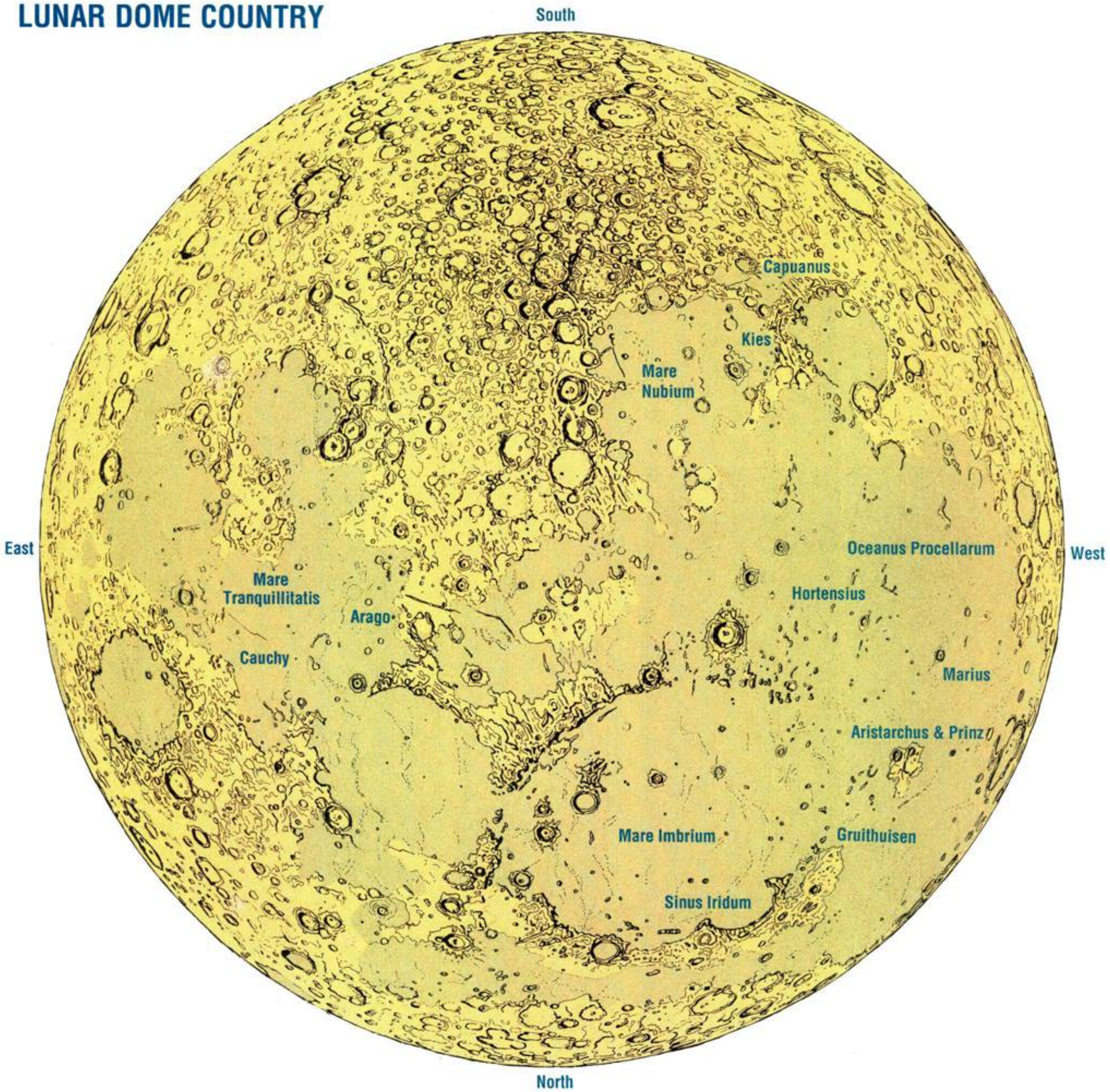

South
Capuanus
Kies
Mare Nubium
East
West
Oceanus Procellarum
Mare Tranquillitatis
Arago
Hortensius
Cauchy
Marius
Aristarchus & Prinz
Mare Imbrium
Gruithuisen
Sinus Iridum
North

Illustration by Richard Berry

side, each about as large in diameter as Cauchy. Named **Cauchy Omega** and **Cauchy Tau**, both have tiny summit craters that will challenge the resolving power of a medium-sized scope (a 4-inch refractor or a 6-inch reflector).

On the very next night, we can see two of the most prominent domes on the Moon. On the western shore of Mare Tranquillitatis, almost due west of Cauchy, lies the fresh crater Arago, 16 miles in diameter. One crater-width due north is the dome **Arago Alpha**, while **Arago Beta** lies one crater-width due west. Both domes are unusually tall and have complex surfaces, unlike the smooth blister we usually see. Another crater-width north of Alpha Arago and slightly to the west is an interesting group of four tiny, low domes that can be seen only right after local sunrise or just before sunset, five or six days after Full Moon.

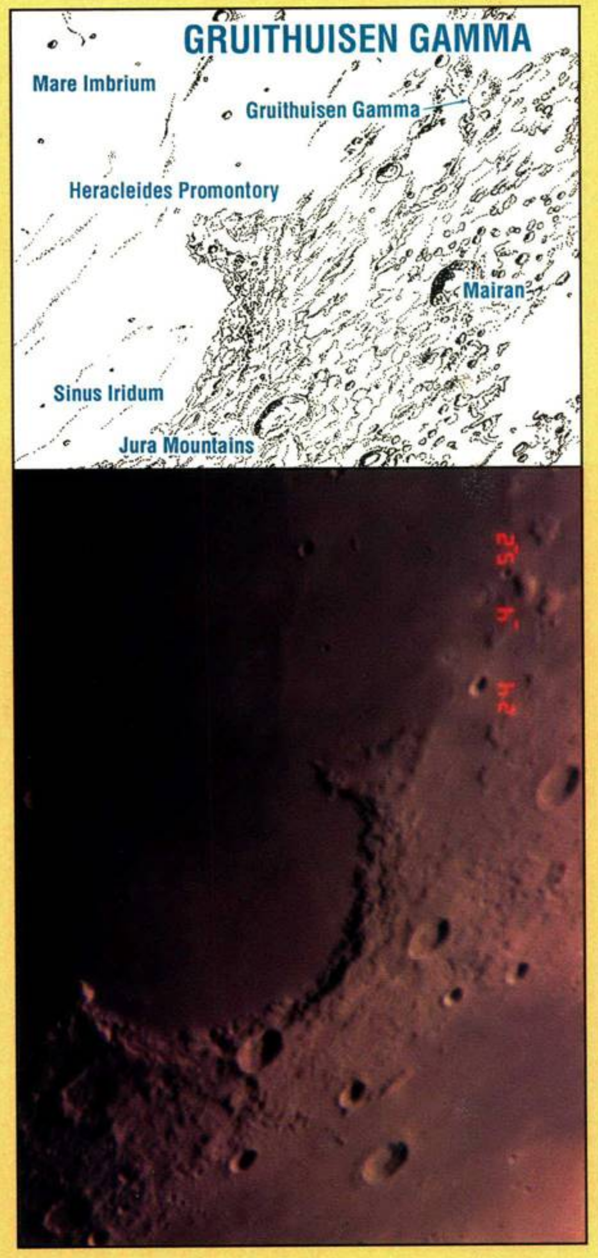
On the tenth evening after New Moon, the terminator is on the Moon's western hemisphere, which contains a spectacular collection of domes. In Mare Nubium lies Bullialdus, a 37-mile-diameter crater. About two crater-diameters south of it is a ghost crater named Kies, 27 miles across. The walls of Kies are mostly destroyed and its floor completely inundated with lava. Just outside its western wall lies **Kies Pi**, a textbook lunar dome. It is smooth, gently sloped, and featureless except for a craterlet at its exact center. This summit pit is fairly easy to observe. Due south of Kies, past a low highlands region cut by the Hesiodus Rille, is a small patch of mare called Palus Epidemiarum. On its southern shore is the highly degraded crater **Capuanus.** Within this 37-mile-wide crater lie four elongated featureless domes.

To the north of Mare Nubium on that same evening, the great crater Copernicus (58 miles across) is outstandingly eye catching. West from Copernicus a distance of two crater-diameters is the sharp-rimmed bowl crater **Hortensius**, 9 miles in diameter. Just north of Hortensius is an exquisite grouping of five perfectly shaped but unnamed domes, each with tiny summit pits. Northwest of Hortensius is a similarly sized bowl crater, Milichius. (These are the only two such craters in the area, making identification easy).

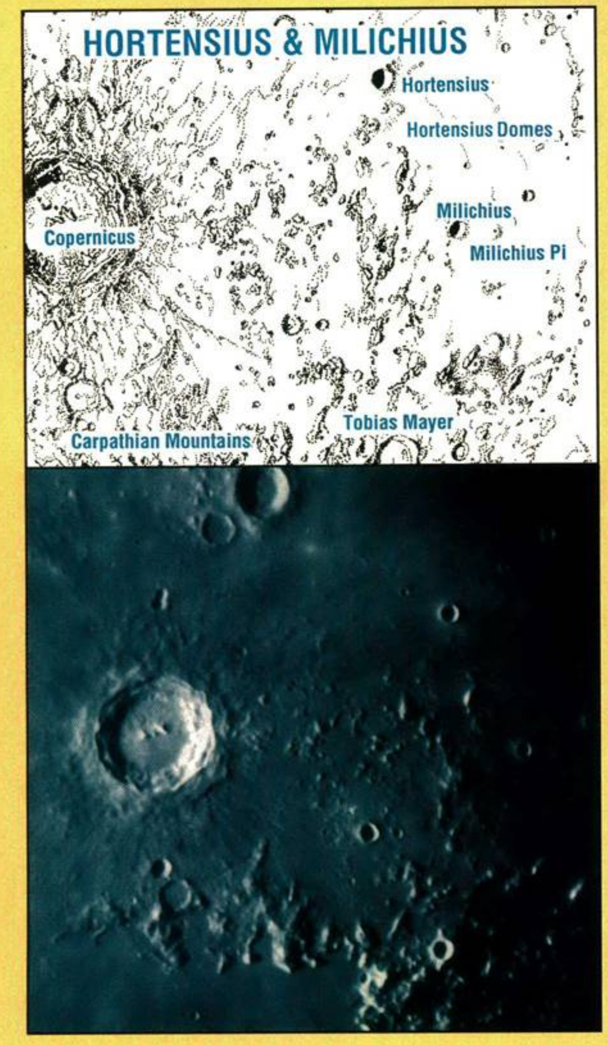
Just west of it you'll find the dome **Milichius Pi**, which also has a nice summit pit. If you're adventurous, look carefully in the hills that lie between Milichius and Tobias Mayer, a 20-mile-wide crater lying at the western end of the Carpathian Mountains. This hilly region abounds in unnamed, low-profile domes.

(Incidentally, the floor of Copernicus also has numerous very tiny domes strewn across it. On a night of good seeing, these make for some interesting high-power exploring.)

On the next evening, the eleventh after New Moon, Sinus Iridum is visible as a giant curved sickle in the Jura Mountains that form the northwest edge of Mare Imbrium. In the highlands due west of the Heracleides Promontory lies the 25-mile-wide crater

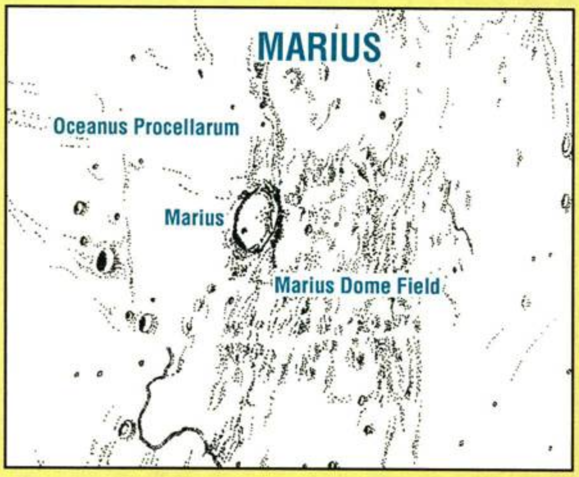

GRUITHUISEN GAMMA
Mare Imbrium
Gruithuisen Gamma
Heracleides Promontory
Mairan
Sinus Iridum
Jura Mountains

SMOOTH AND LARGE, the dome Gruithuisen Gamma is one of the Moon's largest. It is also easy to find, being close to Sinus Iridum. Photo by Jean Dragesco.


HORTENSIUS & MILICHIUS
Hortensius
Hortensius Domes
Milichius
Copernicus
Milichius Pi
Tobias Mayer
Carpathian Mountains

MORNING OVER COPERNICUS also reveals a small dome field north of Hortensius; these are easy to spot in even a small scope. Milichius also has several low domes in its vicinity. Photo by Jean Dragesco.

Mairan. South of Mairan, and making almost a right angle with it and the promontory, is the unique dome **Gruithuisen Gamma**. The dome lies in the region where Mare Imbrium merges into Oceanus Procellarum.

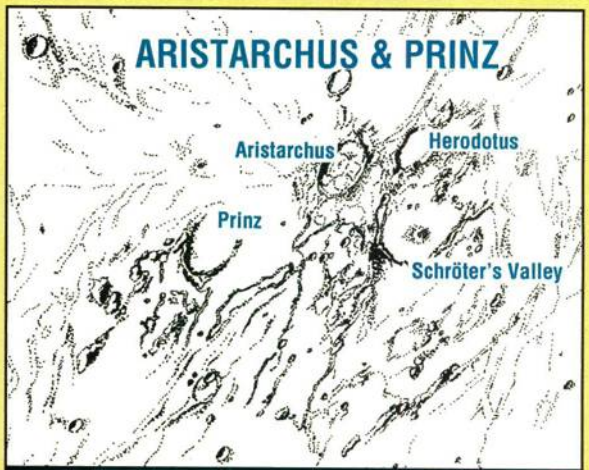


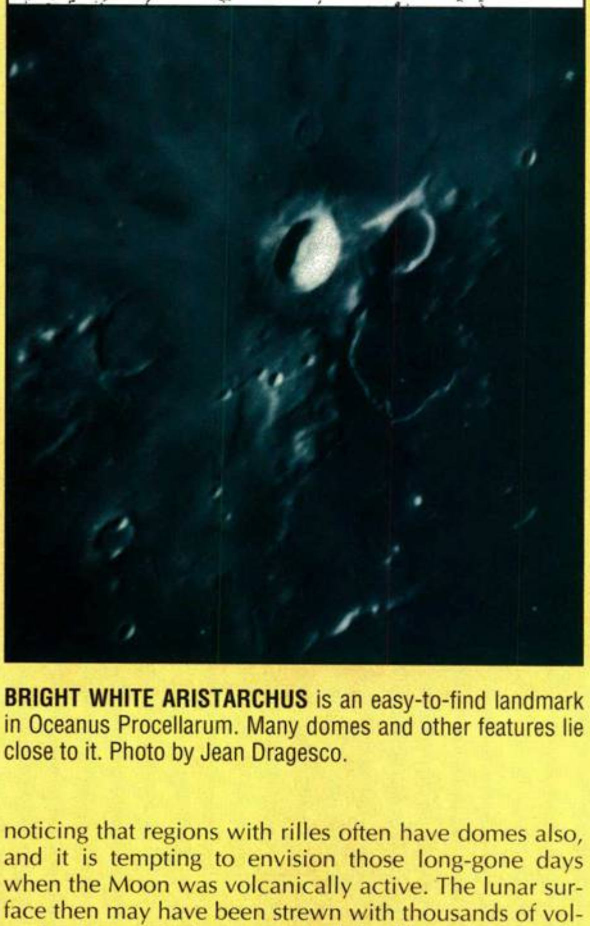
The dome has been described as looking like an overturned bathtub or an oblong cough drop. Located as it is next to a hilly region, you may not spot it at first. But its smooth appearance and distinctive shape will soon grab your attention. Gruithuisen Gamma is one of the tallest domes on the Moon, and it has a summit crater that can be difficult to spot.

Twelve nights after New Moon, the terminator is crossing the western reaches of Oceanus Procellarum. Due west of Copernicus and due south of the bright crater Aristarchus, you'll see the flooded 25-mile-wide crater **Marius**, one of the few craters in the area. As the terminator creeps westward past Marius, one dome after another will be revealed until a huge field (about 100 miles square) is unveiled, strewn with them. The Marius dome field is the largest concentration of extinct volcanos on the Moon. Spacecraft photos from lunar orbit show hundreds of domes here, and at least twenty or thirty are large enough to be seen with medium magnification. The Marius domes are all small; few will show details in any but the largest backyard scopes.

After prowling through the Marius hills, move northward to the area surrounding **Aristarchus** (28 miles across) and the flooded semicircular crater **Prinz** (32 miles across) that lies to the northeast. This entire area is one of the Moon's most geologically complex, containing numerous rilles and unnamed domes. A slow scan across this region will reward you with many interesting sights. For example, the famous sinuous rille, Schröter's Valley, originates in a dome that was breached by lava and is now greatly destroyed. Also, the Valley crooks around a moderate-sized, low-relief dome with a summit pit. Small domes appear to be the source of a group of eight very fine rilles located immediately north of Aristarchus. Likewise, three additional rilles emanate from small domes just north of Prinz. All these features will require very steady seeing and magnifications of at least 250x.

As you scan the Moon for domes, you can't help noticing that regions with rilles often have domes also, and it is tempting to envision those long-gone days when the Moon was volcanically active. The lunar surface then may have been strewn with thousands of volcanic domes, cinder cones, and the like. What a sight it would have been to see eruptions through a telescope! What would you see? Red-hot tongues of lava — or plumes of fine volcanic ash?





BRIGHT WHITE ARISTARCHUS is an easy-to-find landmark in Oceanus Procellarum. Many domes and other features lie close to it. Photo by Jean Dragesco.

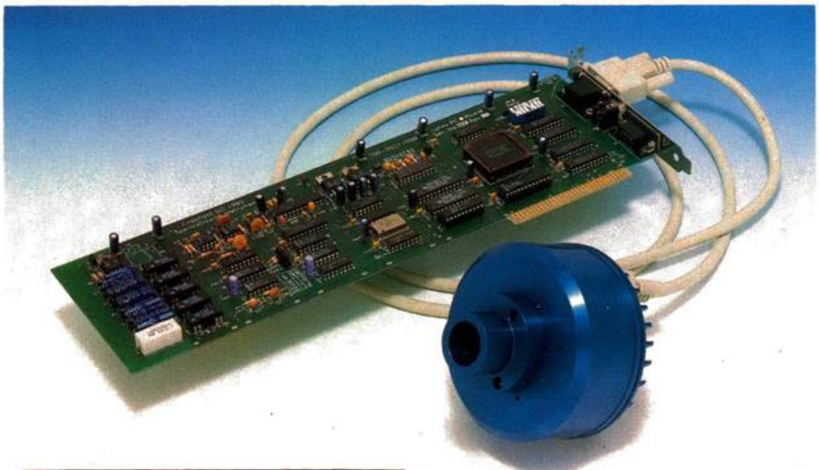
The lunar fires have been cold for ages now, and the surface is eternally still. But it takes only a telescope and a little imagination to transport you back to the days when the Moon was a young and violent place. ☐

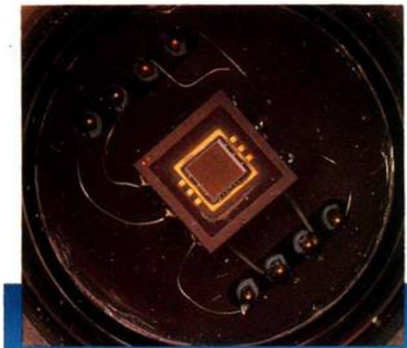
Michael T. Kitt is a longtime member of the Association of Lunar and Planetary Observers. His last ASTRONOMY article was "Observing the Apollo Landing Sites" in the July 1989 issue.

ASTRONOMY Compares Two CCD Cameras

The Lynxx-PC and ST-4 CCD systems offer an inexpensive way to get started in digital imaging. Our comparison shows that both cameras are capable of producing good pictures, but the Lynxx is better for serious imaging.

by Richard Berry





LOW-COST IMAGE SENSORS will enable many observers to try digital imaging. Both the Lynxx-PC (above) and the SBIG ST-4 (below) use the Texas Instruments TC-211 chip (left).

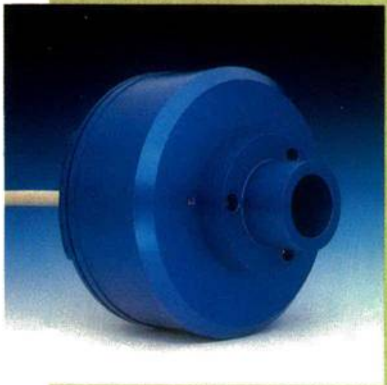
SBIG
ASTRONOMICAL INSTRUMENTS
STAR TRACKER / IMAGING CAMERA
VALUE
TAKE DARK FRAME
FIND AND FOCUS
CALIBRATE DRIVE
TRACK
MODE
SELECT
INTERRUPT
MENU
ADJUST
CCD HEAD
RS-232C
RELAYS
POWER

Two capable and low-cost CCD cameras have attracted interest among amateur astronomers: the SpectraSource Lynxx-PC and the Santa Barbara Instrument Group ST-4. These cameras are closely comparable because both use the same chip, a TC-211 CCD from Texas Instruments. I tested these cameras on small-aperture telescopes under field conditions that many observers are likely to encounter.

Because the ability to capture digital images is common to these products, this review focuses on picture-taking ability. However, comparison on this basis alone is not strictly fair. The Santa Barbara Instrument Group (SBIG) ST-4 is a multi-purpose unit that can serve as a star-tracker for conventional astrophotography as well as an imaging camera, while the Lynxx-PC is a dedicated imaging camera. As you read, bear in mind that this review does not assess the ST-4's star tracking ability.

ASTRONOMY asked SpectraSource and the Santa Barbara Instrument Group for samples of the Lynxx-PC and ST-4. We tested ST-4 camera head and microcontroller units serial numbered 900907. This ST-4 system was originally loaned to Michael Chibnik for his story, "CCD Cameras: Digital Astrophotography is Here," in the October issue of ASTRONOMY. SpectraSource loaned ASTRONOMY their Lynxx-PC computer card serial number 001 and a blue-anodized camera head, the prototype unit for this product. The standard camera head is anodized black.

Evaluation of the imaging abilities of the ST-4 and Lynxx took ten weeks, from mid-June until early September. Most of the testing was conducted in my tiny, one-person observatory using a 6-inch f/5 Newtonian telescope on a Byers 812 mounting. I used two PCs, a Kaypro XT-clone with an EGA graphics card



Lynxx-PC CCD Imaging Camera

A 192- by 165-pixel TI TC-211 CCD camera with built-in shutter and Peltier-effect cooler. PC-based systems include an XT/AT plug-in card; stand-alone units include a digital electronics unit that carries out all camera functions except saving and loading files. Lynxx-Plus units drive an NTSC video monitor.

Manufacturer: SpectraSource Instruments, P.O. Box 1045, Agoura Hills, CA 91376-1045; (818) 707-2655.

List Prices: PC-Based Systems: Lynxx-PC CCD Imaging System, $1,099 (this is the system we reviewed); Lynxx-PC Plus, $1,399; Stand-Alone Systems: Lynxx CCD, $2,975; Lynxx Plus CCD, $3,724. Autoguide Option: $100; 9-Inch NTSC Monochrome Monitor (for use with "Plus" systems), $235. Software is included with camera.

Pros: Produces 12-bit image data, has an integral shutter, and amplifier glow is suppressed. Available with 1.25-inch, 2-inch, and camera adapters. Software displays images with 64 gray-levels on a VGA monitor. Speedy, 2-second screen refresh time with VGA in full-screen focus mode; even faster 1 second refresh with NTSC external monitor.

Cons: Lynxx-PC requires host computer with minimum of EGA or VGA graphics or external NTSC monitor. Star tracker guider option not yet available on PC-based systems.

at first, and later a Samsung 386SX with a VGA card and color monitor.

The Lynxx-PC Digital Imaging System consists of a camera head, full-length XT-style computer card, a cable to connect the camera head and computer card, and a diskette with Lynxx-PC software. The camera head is 4 inches in diameter and 2.5 inches deep. The back of the camera head has fins to dissipate heat from the chip's cooler.

For the Lynxx-PC Plus, you'll need an NTSC or PAL video monitor (the American and European standards, respectively) and a video cable with RCA-style jacks. The Lynxx-PC Plus generates a video signal on the card that drives the video monitor. The less-expensive Lynxx-PC relies on the host computer's graphics card and monitor to display images.

The Lynxx camera head comes standard with a dual 2-inch/1.25-inch focuser adapter, and you can order optional T-mounts or camera mounts. Your telescope should be able to focus 0.7 inches behind the front face of the camera, about an inch less than the thickness of a 35mm camera body. If you mount the Lynxx on a Newtonian with a low-profile focuser, you may need an additional adapter to bring the camera to focus. Alternatively, order a camera adapter and treat the Lynxx as a replacement for a standard 35mm camera body.

The SBIG ST-4 Star Tracker and Imaging Camera consists of a camera head, a microcontroller unit, a 12-volt plug-in power supply, cables, and software for PCs or Macintoshes. The camera head is 3 inches in diameter and 1.5 inches thick, with a 1.25-inch focuser adapter that extends 1 inch from the front face of the camera head. The CCD chip is virtually flush with the front face of the camera head. A ten-foot cable comes from the back of the camera head and is permanently attached to it.

I really like the ST-4's software. In both the PC and Mac versions, pop-down menus allow you to select the graphics mode, set the operating parameters of the camera, and take exposures with just a few keystrokes or mouse movements. Once you have images, you can display them in gray-scale, dithered pixel, or color modes, depending on what graphics adapter your computer has.

I especially appreciated the automatic scaling feature in displaying pictures. When a new image comes from the camera, the program determines the data value to be black and the range of values from black to white. You can set these values yourself, of course, but the auto feature saves a lot of monkeying around.

The Lynxx-PC software is also menu-driven and mouse-oriented, but the Lynxx software is not so user-friendly as the ST-4. At 3 a.m. I found it easy to goof and turn off the cooler when I meant only to reinitialize the stored bias and thermal frames.

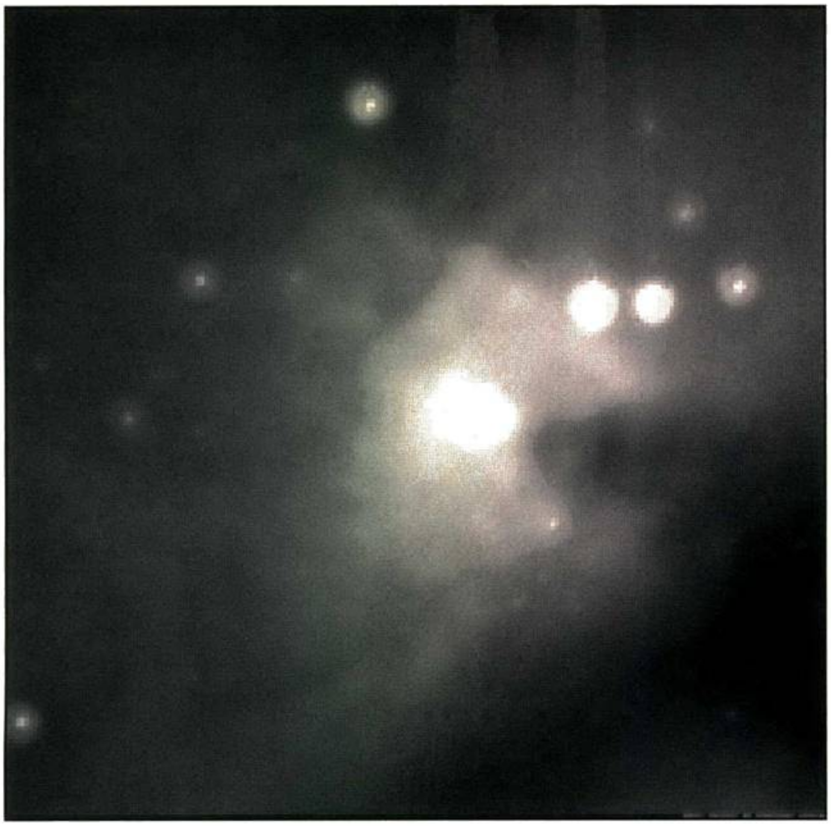
In digital imaging a key concern is background noise, and noise is not necessarily the fault of the camera. I switched computers midway through testing because the PC XT-clone computer I used at first had a problem in its 65-watt power supply that laid faint and fuzzy diagonal stripes across images I took with the Lynxx. After Steve McArthur at SpectraSource tested the Lynxx-PC board and assured me it was okay, I installed the Lynxx-PC board in a 386SX machine with a 200-watt power supply. The stripe problem vanished.

To make images with a CCD, you shoot an image, or "light" frame, and then subtract bias and thermal noise, a "dark" frame, from it. If the CCD and its electronics are good, these are uniform and repeatable. When you subtract a "dark" frame from a "light" frame, the improvement is dramatic.

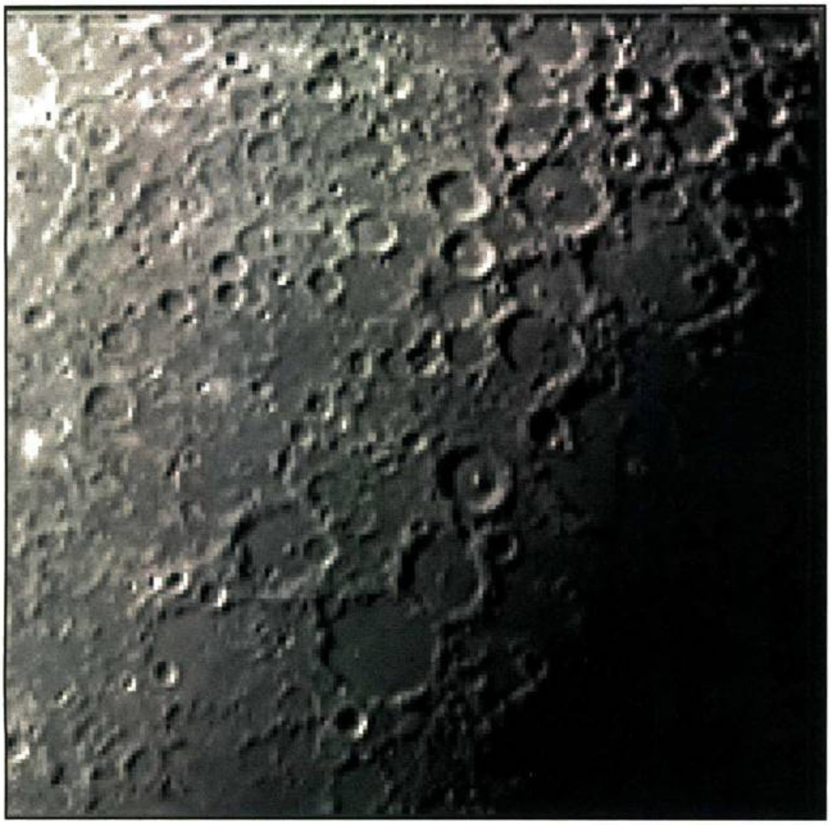
To correct for variations in chip sensitivity, you can also shoot a flat-field frame — a picture of a white wall. You then divide your image data by the flat field to take out sensitivity variations. Flat-fielding removes vignetting as well as pixel-to-pixel variations in the chip.

The Lynxx automatically corrects for bias, thermal, and flat field and also lets you save bias, thermal, and flat frames to disk. The bias and thermal frames I examined were stable and highly repeatable from night to night. The flat frame showed nothing but vignetting and dust in the telescope optics. I made exposures as long as 600 seconds with the Lynxx, and the dark frames were only one-third of the way to saturation. This means exposures of perhaps 20 minutes should be possible with the Lynxx.

The ST-4 does not let you download its stored "dark frame" (the sum of thermal-noise and bias frames) but I got a handle on its thermal noise by taking image frames with the telescope covered. The ST-4 chip shows the same sort of salt-and-pepper that the Lynxx does — but in the ST-4 the on-chip amplifier produces a glow in one corner of the frame. As long as I kept exposures under 200 seconds, the ST-4's automatic dark-frame subtraction removed this glow completely. Two-hundred-second exposures caused that corner of the dark frame to saturate (i.e., reach a value of 255) and the corner glow appeared as a "dead" region. For full-frame pictures, the ST-4 I tested appears to be limited to exposures under 200 seconds.



DIGITAL PRECISION underlies this image of the Orion Nebula, captured in three exposures of 200, 15, and 2 seconds and combined into one image on a PC-clone. Images made with a Lynxx-PC on a 6-inch f/5 Newtonian reflector.



SMALL TELESCOPES ARE GREAT for CCD imaging. At the focus of a 4-inch f/10 Meade 2045, our test Lynxx-PC captured First-Quarter lunar features with an exposure of 1/100 of a second. The built-in shutter made this possible.

THE DIGITAL LYNXX

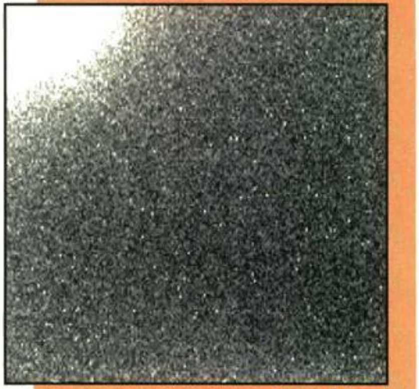
For precision imaging, each image frame must be processed by subtracting the bias and thermal frames and then dividing by the flat-field frame. The Lynxx does this automatically, or the observer can process images manually. Bias frames from our sample unit showed a minor noise signal (8 data numbers amplitude) that was repeatable and could be subtracted out. The thermal frame shows a uniform salt-and-pepper gray, just what you'd like to see. The flat-field shows a smooth variation from the telescope optics; the dark donut is a dust shadow.

Bias Frame

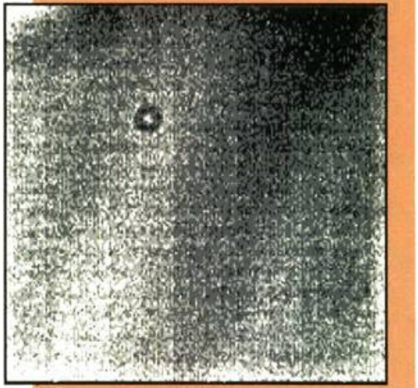
Thermal Frame

Flat-Field Frame

THE DIGITAL ST-4



Dark Frame

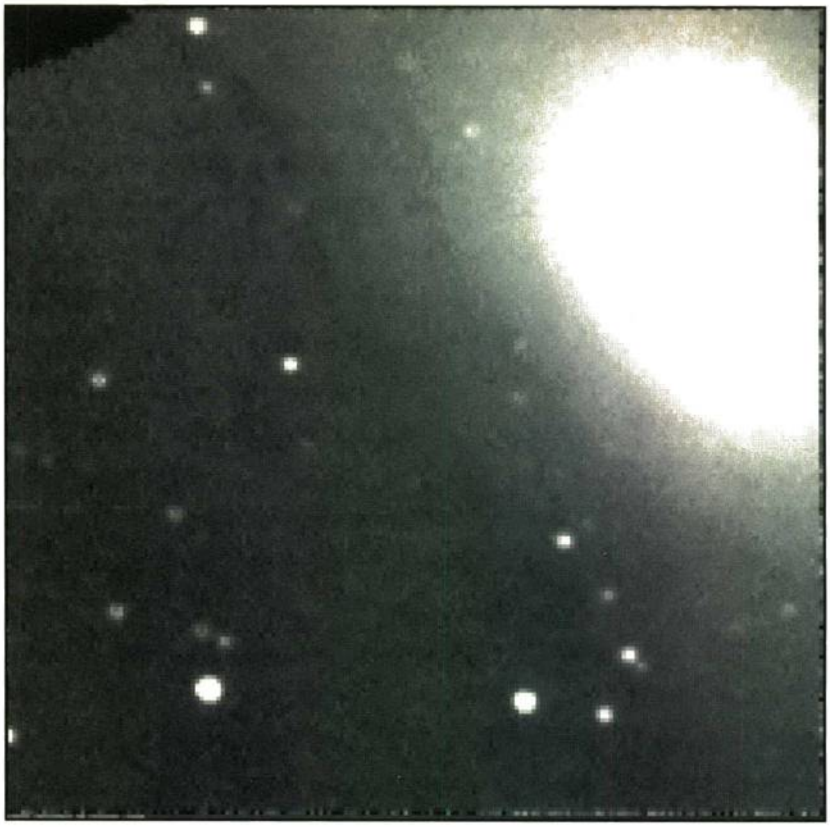


Flat-Field Frame

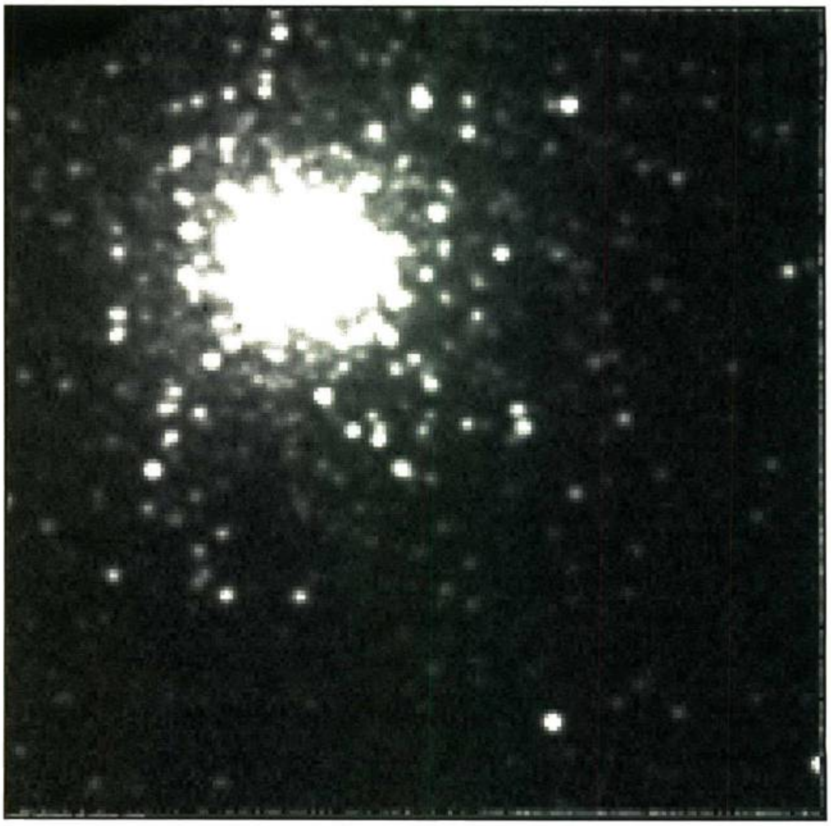
The ST-4 is designed to take and automatically subtract a dark frame from an exposure, or "light frame." (In the ST-4, a dark frame is equivalent to the sum of the Lynxx bias and thermal frames.) Because dark frames cannot be downloaded for examination, our dark frame is simply an exposure with the aperture of the telescope covered.

The dark frame is a uniform salt-and-pepper gray with a strong signal in the upper left corner due to the glow of the amplifier. If the CCD is not saturated by the glow, the glow disappears from the image when the ST-4 subtracts a dark frame.

The ST-4 does not presently have provision for flat-field correcting images. I obtained a flat-field exposure by imaging the illuminated wall of the observatory. The flat-field image shows a regular checkerboard pattern with a peak-to-valley variation of 4 data numbers, or about 2.4 percent. This pattern could also be seen in some of the images I took, but dividing by the flat-frame greatly reduced its visibility.

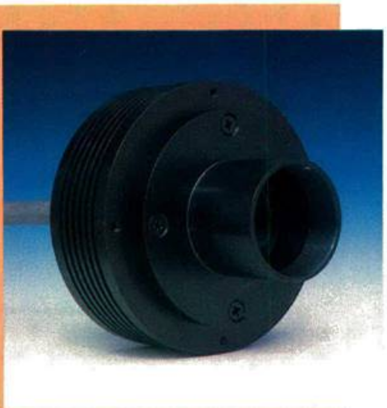


CLOSE-UP DETAIL in the Andromeda Galaxy shows a "big telescope" field of view with a short-focus telescope. The nucleus of the galaxy is overexposed, but the near-side dust lanes show in silhouette against the galactic disk.



HUNDREDS OF STARS in the globular cluster M13 show in this 200-second exposure made with an ST-4 on a 6-inch f/5 Newtonian reflector. The extreme corner of the dark frame saturated due to amplifier glow and appears black.

ST-4 Star Tracker and Imaging Camera



A dual-purpose star-tracker and imaging camera based on a TI TC-211 192- by 165-pixel CCD with built-in Peltier-effect cooler. Includes microcontroller unit that controls the camera and communicates with PC and Macintosh computers via RS-232 serial interface. The system functions as a stand-alone star tracker.

Manufacturer: Santa Barbara Instrument Group, 1485 East Valley Road, Suite #J601, Santa Barbara, CA 93108, (805) 969-1851.

List Price: Model ST-4 Star Tracker and Imaging Camera, $890; demonstration diskette, $5. Software is included with the camera.

Pros: Camera head is small, unit is low in cost, light in weight, and interfaces via serial cable with PCs, PC clones, and Macintoshes. Runs on 12 volts DC for field operation. PC software works with CGA, EGA, VGA, and Hercules graphics and monitor; Mac software works with all Macs. Software measures brightness, separations, and position angles of star. Excellent low-cost star-tracker for conventional astrophotography.

Cons: 8-bit image data offers small dynamic range for astronomical imaging. Lack of built-in shutter makes imaging Moon and planets difficult. Amplifier glow limits length of useful exposures on deep-sky objects. Good display of images requires color or gray-scale monitor.

I discussed the glow with Matt Longmire at SBIG, and he told me that the ST-4 chip is now more efficiently cooled and that the camera can now expose twice as long before saturation. If you don't mind a small black area in the corner of your frames, exposures can be longer still.

In several ST-4 images I also noticed a low-contrast background pattern that looked like shingles on the roof of a house. To root out the problem, I made flat-field frames of the twilight sky. The "shingles" turned out to be a semi-regular checkerboard variation of about 2 percent in amplitude. This variation is small and may not be representative of other SBIG ST-4 cameras. I found that I could divide out most of the pattern using other image-processing software, but the ST-4 software has no provision for flat-fielding. Longmire said that such software is now under development. I flat-field corrected the images shown in this review.

The Lynxx digitizes picture data to 12-bit accuracy, or 1 part in 4096. The ST-4 produces 8-bit data, accurate to 1 part in 256. Twelve-bit data allows you to detect much smaller brightness differences but takes more space to store an image on disk. A Lynxx image file is 47,520 bytes long whereas an ST-4 file is 31,872 bytes.

I examined the images I had taken with both systems to see how important 8-bit *versus* 12-bit data is. On bright and contrasty objects like M57 or M13, I could not see the brightness steps. For these, 8-bit data is fine. To capture faint, low-contrast objects like the California Nebula, you need the 12-bit data that the Lynxx offers.

Its built-in shutter gives the Lynxx a further imaging advantage. In the ST-4, light always falls on the chip. If the subject is bright, the chip continues to register light even as you read data out, smearing the picture. To photograph planets, therefore, you must place the planet's image on one side of the chip and use a special half-frame mode to transfer data out of the active imaging area.

With the Lynxx, you can center a bright, extended subject such as the Moon, trigger the shutter, and then read out a full frame of data. Although I did not shoot high-resolution planetary images, I suspect the Lynxx has considerable potential for planetary observers. With the ST-4, you cannot take Moon pictures unless you use filters to purposely lengthen the exposures to at least 1 second, which defeats the purpose of using a highly sensitive CCD chip.

The choice between a Lynxx and an ST-4 depends largely on whether you want images or guiding from your CCD system, what computer you own, and how much you can afford to spend on your hobby. If you use a Macintosh, for example, the Lynxx-PC is simply not an option. Basically, if you want a low-cost star tracker to guide hour-long exposures while you enjoy the sky, the ST-4 is the clear choice. For imaging, however, my choice is the Lynxx-PC.

The Lynxx-PC is optimized for picture taking. The suppression of amplifier electroluminescence, the 12-bit resolution, and the integral shutter make it the clear choice for digital images. The Lynxx system, however, represents a fairly hefty investment. A minimum system should include either a Lynxx-PC ($1,099) and an XT or AT clone equipped with a VGA graphics card and monitor (roughly $600 for the graphics system), or a Lynxx-PC Plus ($1,399) with an NTSC monochrome monitor ($235). Overall, I found the Lynxx-PC a powerful and versatile camera system able to record familiar deep-sky objects in 3-minute exposures and capable of exposures longer than 10 minutes, with sufficient resolution in the data to produce excellent gray-scale images.

The SBIG ST-4 system is optimized for automatic guiding of conventional astrophotographs. It also offers the buyer an excellent opportunity to get into digital imaging for only $890. The system is simple, compact, and designed to interface with both Macintoshes and PCs. It works with CGA, EGA, VGA, and Hercules graphics on the PC-XT and AT and with the ordinary black-and-white, gray-scale, or color graphics on the Macintosh. For celestial imaging the amplifier glow in the corner of the frame is very annoying, and the 8-bit data resolution limits image processing. I do not hesitate to recommend the ST-4 as a good, low-cost way to get started with CCDs and electronic picture taking. After all, I was able to get good pictures with it.

Testing the Lynxx and ST-4 for this review was a lot of fun. It was great to see celestial objects pop up on the computer screen moments after I had ended an exposure and to immediately bring out more detail. I also found considerable satisfaction in working through the problems I encountered — finding the fields I wanted, focusing, and figuring out the software.

On cloudy nights I found further satisfaction in stretching image data for the best possible picture quality and studying the images of objects I had captured on clear nights. Both the Lynxx and the SBIG ST-4 provided that satisfaction — and that, after all, is the bottom line in amateur astronomy. □

Observe the Geminids Before They Disappear

The Geminid meteor shower is one of the year's best, but the annual show may last only a few more years.

by Philip M. Bagnall

This month, grab your parka, lawn chair, and a flask of hot chocolate and head out for an evening of meteor watching. On the night of December 13/14, the moonless skies should be ablaze with a fireworks display as the Geminid meteor shower reaches its peak activity.

Today, most experienced observers consider the Geminids the most prolific of the dozen or so major annual streams, surpassing even the popular Perseids of August.

Geminid activity normally starts on about December 7 and runs until the 16th. Maximum activity should occur during the early evening hours of December 13 for North American observers (early morning hours of December 14 for British and European viewers), though the exact hour of the peak is uncertain: the British Astronomical Association says December 14 at 3h UT, while the Royal Astronomical Society of Canada's *Observer's Handbook* says December 14 at 11h UT. In either case, the Moon will be 27 days old and absent from the sky, leaving the heavens dark enough to observe even the more numerous faint meteors.

If you happen to live in the southern United States, the radiant is high overhead for much of the night, resulting in perhaps 80 to 90 meteors per hour. For those that live further north, the radiant is closer to the southern horizon. As a result the rates fall slightly. Even so, both Canadian and northern European observers can expect to see 65 to 75 meteors per hour at maximum.

The Path of the Meteors

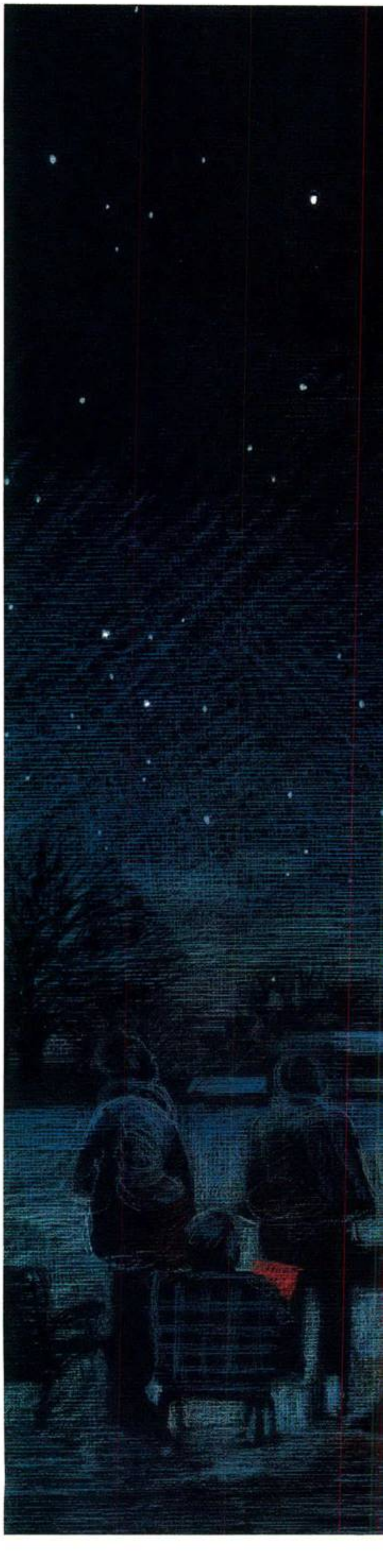
Despite their excellent annual showing, time may be running out for the Geminids. Their orbit is shifting, carrying the densest part of the meteor stream away from Earth.

The meteoroids that make up the Geminid stream orbit the Sun in an elongated path that takes them to within 12 million miles of the Sun. At the other extreme, the Geminid stream stretches out to the asteroid belt, 230 million miles in the opposite direction. Individual meteoroids take between 1.5 and 1.65 years to complete one orbit of the Sun, the shortest orbital period of all the major streams.

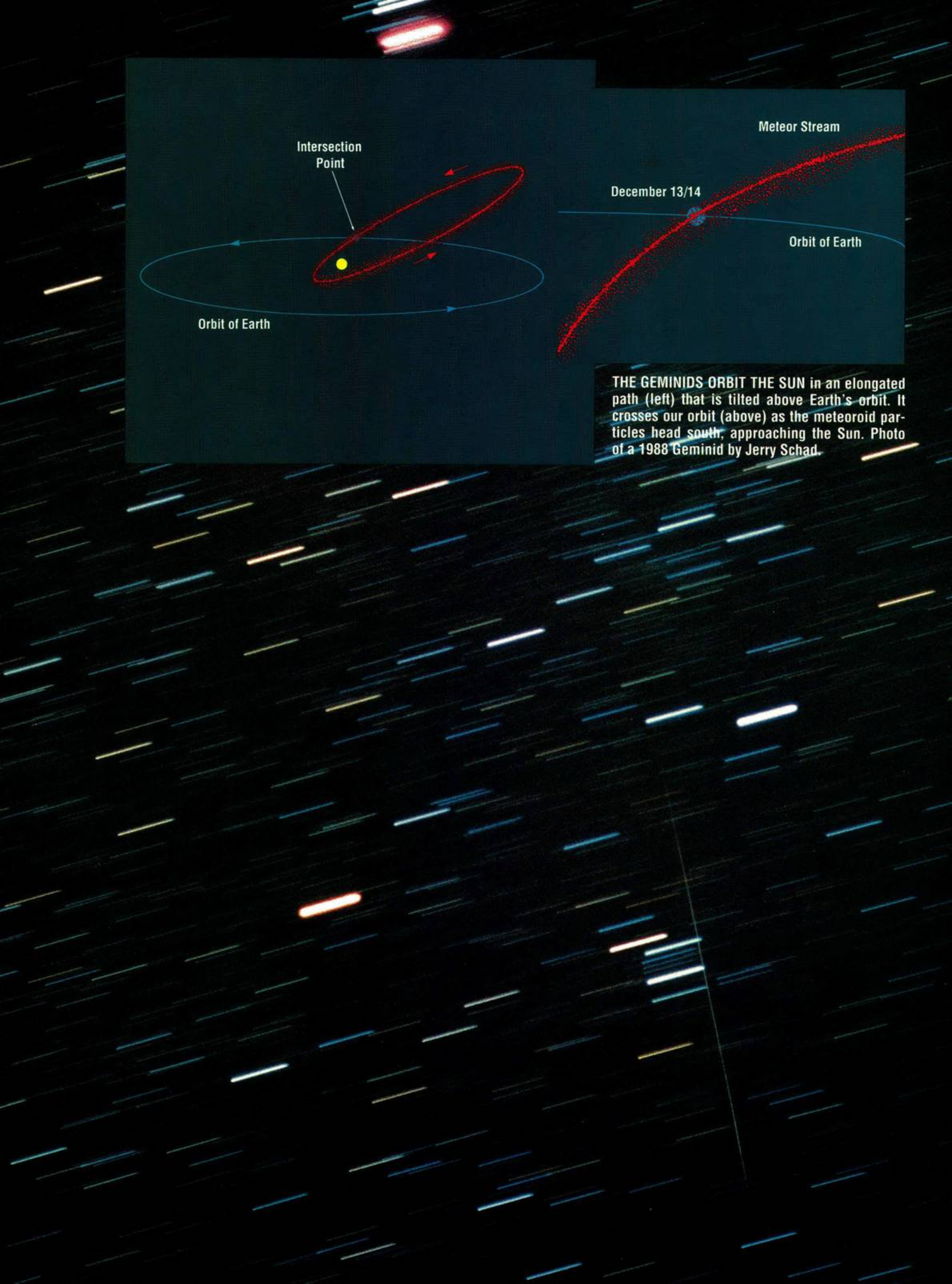
The orbit is also inclined at 23.9° to the ecliptic, the plane of Earth's orbit. The two orbits intersect at the point where the meteoroids cross our orbit traveling north to south. As a result, from our vantage point the meteor shower appears to come out of the northern sky, radiating from a point near the star Castor (Alpha Geminorum). However, the whole stream is moving sideways relative to Earth. This has produced a rapidly changing pattern of activity over the past century.

In order to understand the Geminids, three British researchers have devised a computer model of the stream's behavior. Ken Fox, Ivan Williams, and David Hughes, of Sheffield University, have estimated that the comet responsible for the Geminids first approached the inner solar system about 15,000 years ago. As it warmed and disintegrated, it ejected a stream of dusty particles along its orbit. Over the centuries, gravitational and non-gravitational forces started to disperse the particles.

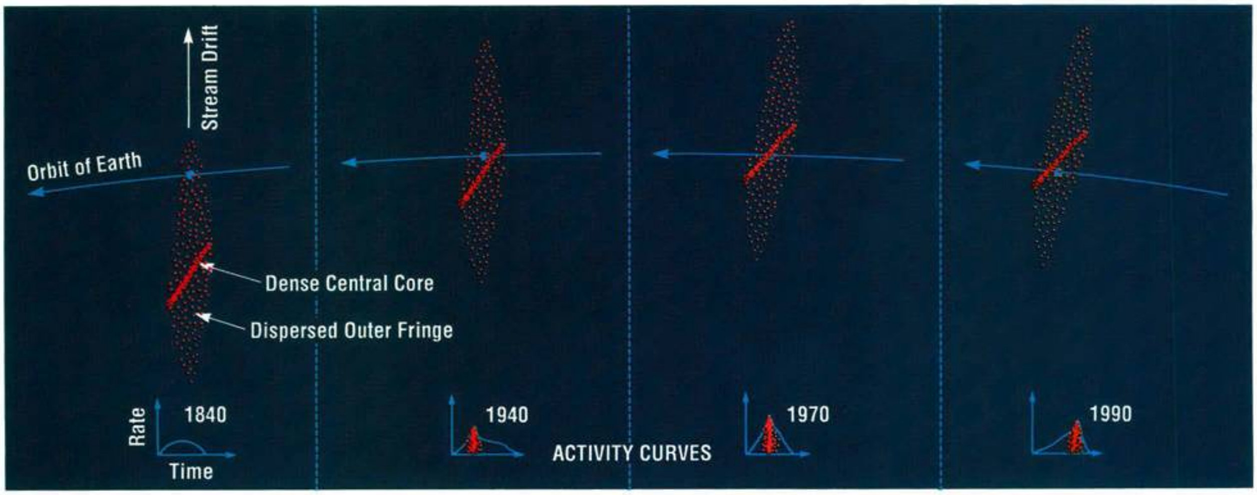
The principal non-gravitational force is the Poynting-Robertson effect, which causes meteoroids to spiral in toward the Sun; the smaller the particle, the faster its orbit decays. Hence over time, the stream became spread out in width, with the smallest particles (which produce the faintest meteors) lying on the sunward side of the orbit. Eventually the stream was pulled and tugged so much that today it looks, in cross-section, as though the particles have been scattered into



A FROSTY NIGHT AND "FALLING STARS" could combine this month to produce a unique observing experience — a winter meteor watch. Illustration by Bruce Bond.


Intersection Point
Orbit of Earth
Meteor Stream
December 13/14
Orbit of Earth

THE GEMINIDS ORBIT THE SUN in an elongated path (left) that is tilted above Earth's orbit. It crosses our orbit (above) as the meteoroid particles head south, approaching the Sun. Photo of a 1988 Geminid by Jerry Schad.



THE GEMINID SWARM has drifted past Earth over the last 150 years. Today our orbit still intersects the densest part of the meteor swarm, but by the early 21st century we will miss this core entirely. The way the shower has peaked has also changed over the years, with today's shower rising slowly to maximum and dropping off sharply.

a distorted ellipse surrounding a much denser central core. The dense core is responsible for the peak activity during the 9-day shower.

While many meteoroid streams are associated with identified comets, no one has yet been able to find the comet responsible for the Geminids. What has been discovered, however, is an object that looks like an asteroid and is now called 3200 Phaethon. It orbits the Sun in a path very similar to that of the Geminids. Is this the burned-out core of the ancient comet that spawned the Geminids? Some researchers feel it is. But it could be that Phaethon is a genuine asteroid that was simply perturbed into an orbit that coincides with that of the Geminids.

The Geminids through Time

The first mention of the shower was made in 1838 by E. C. Herrick in the English magazine *Silliman's Journal*. At that time activity was so weak that it went largely unnoticed until it was rediscovered in 1862 by Robert Greg in England and by B. V. Marsh and Alex Twining in the United States.

Over the next half century, rates slowly increased. By the 1930s the shower was well established and showed a rapid rise to a maximum over one or two days, followed by a slow, gradual decline in activity lasting for about a week. Within the following few years the profile changed completely, giving way to a gradual rise and fall, producing a very symmetrical activity curve.

Nowadays the situation is exactly the opposite of that witnessed during the 1930s. We now see a slow buildup to a very sharp peak after which the activity suddenly collapses. It appears that Earth now passes from the inside (the sunward edge) to the outside of the stream and thus we encounter the smallest meteoroids first. The net result is that the faintest meteors peak first, followed by progressively brighter meteors, until the most brilliant meteors (magnitude –2) reach their peak. After that, activity falls off sharply.

So how does all this fit in with what we know about the stream from the computer model? Because the stream is drifting sideways relative to Earth, Earth never passes through the same section twice. Indeed, prior to about 1750 Earth did not encounter the stream at all. As it began drifting across Earth's orbit we started to pass through the outer fringes where the density of the particles is very low. The result — only weak meteor activity.

Our planet probably first encountered the dense core of meteoroids around 1920 when rates suddenly picked up. From then until the mid-1960s, Earth passed closer and closer to the stream's core at each return, but because the core is angled across the width of the stream, the peak of shower activity occurred later and later each year. If the computer model is correct, we will miss the core completely by the turn of the century and rates will plummet. Within a hundred years, Earth and the meteoroid stream will have parted company. The Geminids will have vanished from our skies after only 350 years.

What to Look For

As the situation changes literally from one year to the next, backyard observers who monitor Geminid activity can make an important contribution. Their observations can be used to test the computer model. To do this, scientists need data on basic features such as the hourly count, magnitude distribution, and colors of bright meteors.

If you undertake an all-night watch on December 13/14, you should find the rate varying during the night. A careful count will help pin down the exact peak hour. It would also be useful to have duration estimates of any persistent streaks meteors leave behind and details of the appearance of these meteor "trains." Records tend to indicate that only about three percent of Geminids leave trains. This is an unusually low percentage among meteor showers.

If you enjoy watching the Geminids and wish to submit reports, contact either the Association of Lunar & Planetary Observers (P.O. Box 16131, San Francisco, CA 9 4166), the American Meteor Society (Department of Physics and Astronomy, State University of New York, Geneseo, NY 14454), or the British Astronomical Association (Burlington House, Piccadilly, London, England WIV 9AG).

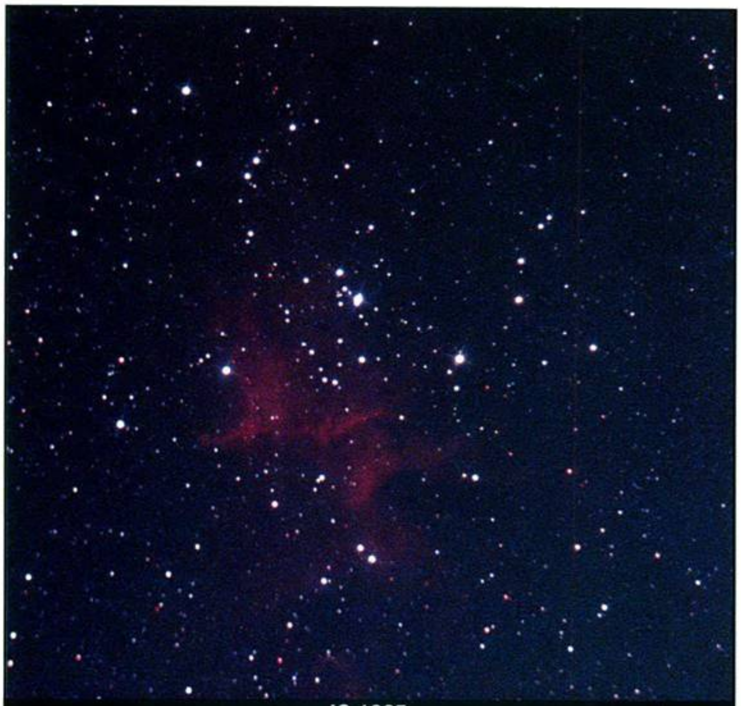
Good luck with your December meteor watch. While you may have to bundle up to endure the cold night air, the reward could the best meteor show of the year. ☐

Phil Bagnall, an amateur astronomer living in northern England, has contributed a number of articles to ASTRONOMY. He profiled the Quadrantid meteors in the January 1987 issue and the Perseids in the August 1988 issue.

The Challenge of Winter Nebulae

Push your telescope and your observing skills to the limit by finding these incredibly faint wisps of light.

by Phil Harrington



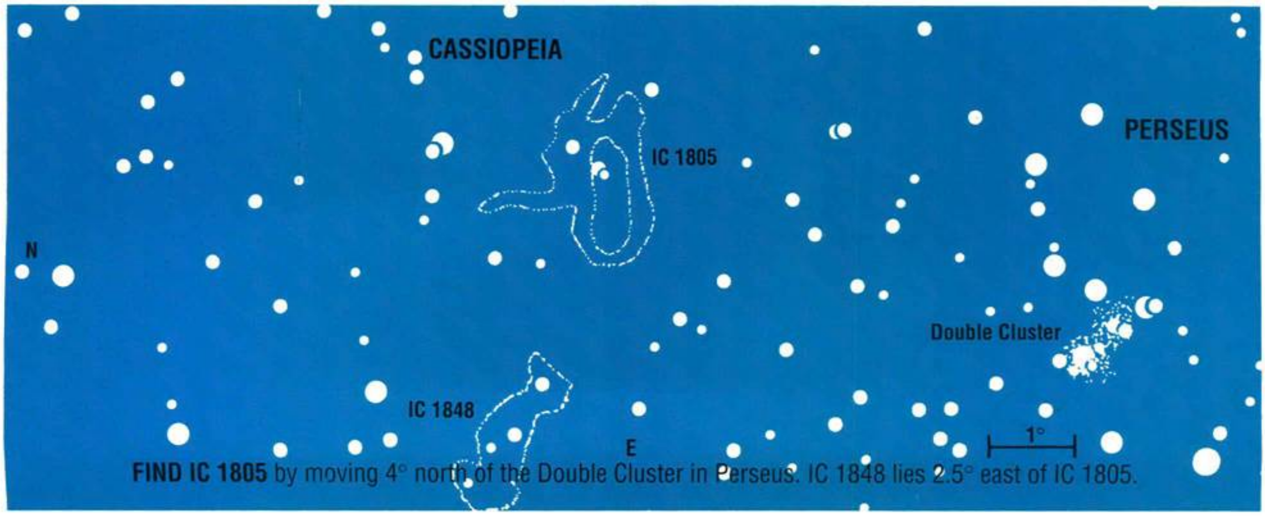
IC 1805
Size 60' by 60' by Jack Newton

Nebulae get a bum rap. Many amateur astronomers think that most nebulae are only visible in long-exposure photographs. While this might have been true twenty or thirty years ago, the popularity of large, fast Newtonian reflectors, advanced multicoated eyepieces, and contrast-enhancing nebula filters have all helped to bring many once-too-faint nebulae into the realm of backyard astronomers.

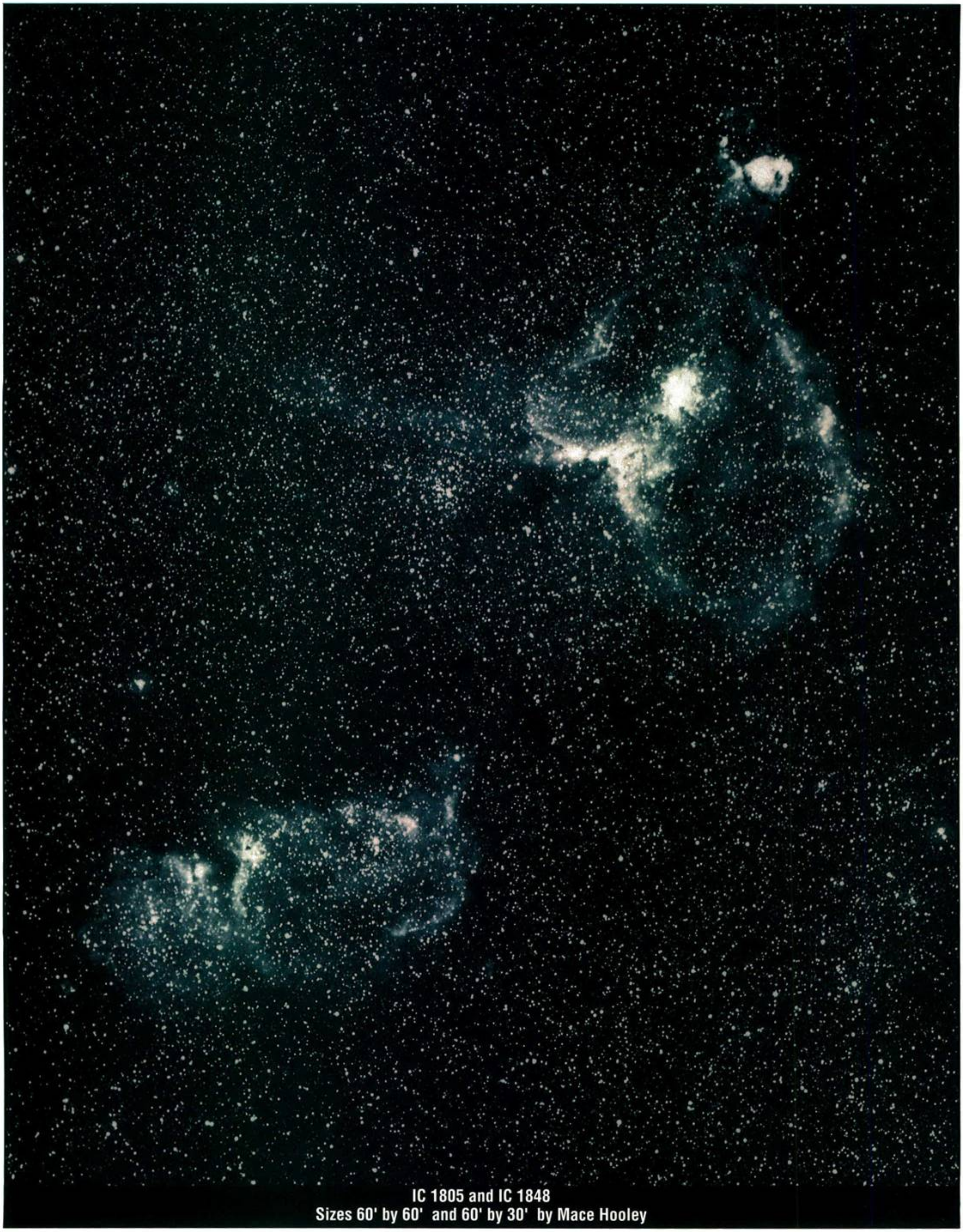
In fact several examples of challenging emission and reflection nebulae are scattered across the winter sky. These objects are not easy to spot, mind you, but they are within the grasp of moderate-sized backyard scopes and will challenge the combination of your eyes, observing site, and telescope.

As a warm up, begin with two huge loops of nebulosity in Cassiopeia the Queen, which is known to deep-sky observers as the home of many pretty open clusters. Just beyond the eastern tip of Cassiopeia's W-shaped asterism is the pair of star clusters **IC 1805** and **IC 1848**. Both are visible in binoculars and finderscopes as small, tight knots of three or four stars. Switching to a 6-inch or larger telescope unmasks each as a large, loose open cluster. Each of these star clusters has a large cloud of nebulosity associated with it. The star clusters are easy to see; the nebulae are more challenging.

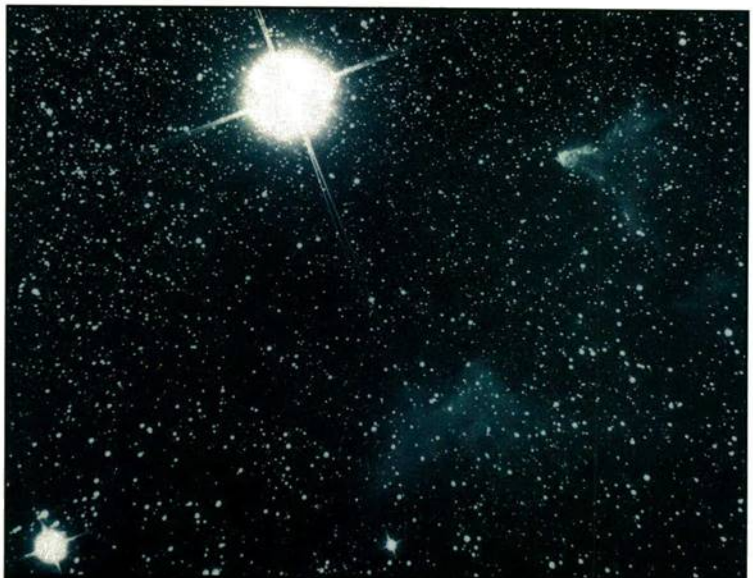
IC 1805 (labeled as Melotte 15 on some star atlases) is the richer of the two. Within this star group's



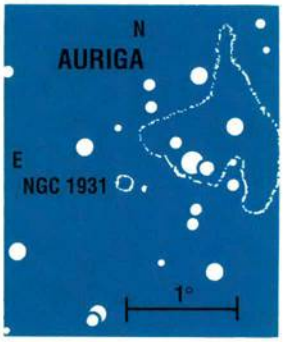
FIND IC 1805 by moving 4° north of the Double Cluster in Perseus. IC 1848 lies 2.5° east of IC 1805.



IC 1805 and IC 1848
Sizes 60' by 60' and 60' by 30' by Mace Hooley

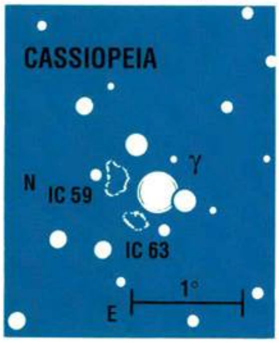


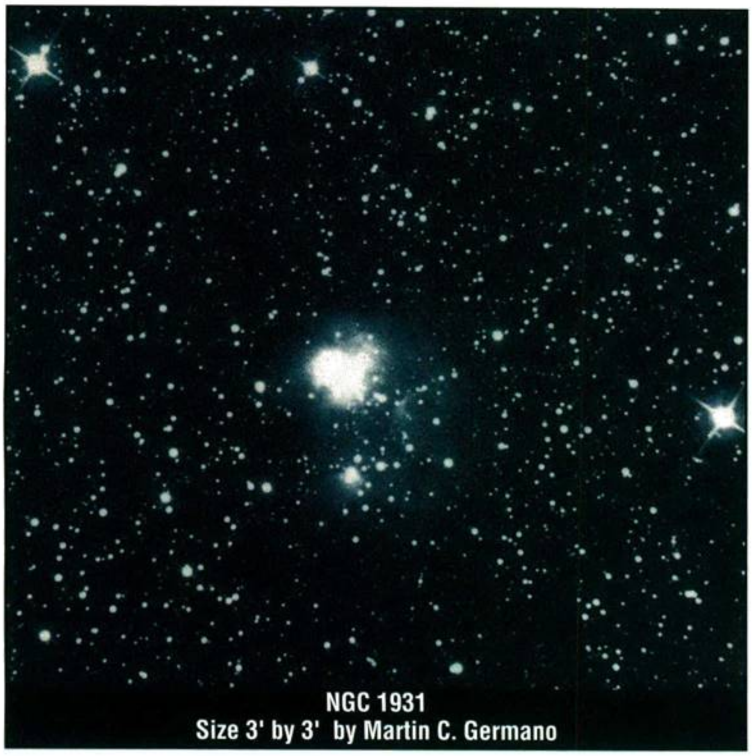
IC 59 and IC 63
Sizes 10' by 5' and 10' by 3' by Martin C. Germano



EMISSION NEBULA NGC 1931 is located 1.5° east of the 5th-magnitude star Phi Aurigae.

IC 59 AND IC 63 lie 20' north and east of the bright star Gamma Cassiopeiae.





NGC 1931
Size 3' by 3' by Martin C. Germano

CHALLENGING WINTER NEBULAE

Object	R.A.(2000.0)Dec.	Type	Size
IC 59	0h56.7m +61°04'	E+R	10' by 5'
IC 63	0h59.5m +60°49'	E+R	10' by 3'
IC 1805	2h33.4m +61°26'	E	60' by 60'
IC 1848	2h51.3m +60°25'	E	60' by 30'
NGC 1579	4h30.2m +35°16'	R	12' by 8'
IC 405	5h16.2m +34°16'	E+R	30' by 19'
IC 410	5h22.6m +33°31'	E	40' by 30'
NGC 1931	5h31.4m +34°15'	E+R	3' by 3'

Object: Designation in NGC or IC catalog. **R.A. and Dec.:** Right ascension and declination in equinox 2000.0. **Type:** Emission (E) or reflection (R) nebulosity. **Size:** Diameter in arcminutes.

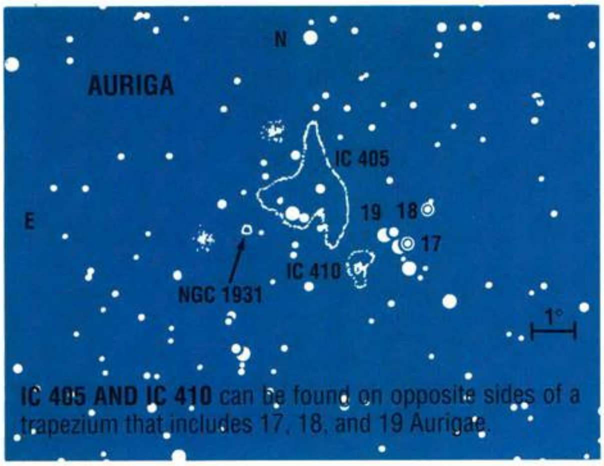
grasp lie forty 8th-magnitude and fainter stars splashed across a 22' diameter. To find IC 1805, start at Epsilon (ε) Cassiopeiae, the easternmost star in the W-shaped asterism. Sliding just over 3° east, watch for a pair of 7th-magnitude stars set in a rich Milky Way field. From here, continue another 2.3° southeast, where you will spot IC 1805.

Surrounding the cluster's stars are the faint remains of the clouds from which they were formed. The brightest portion of the IC 1805 nebula lies southwest of the cluster's brightest stars. Under an exquisitely dark sky last winter, my 13.1-inch f/4.5 Newtonian revealed faint, grayish arcs of light set between the clusters. Although no fine detail was visible, the cloud's eastern boundary appeared sharp and distinct. The western edge was diffuse and ill-defined.

Because the IC 1805 nebulosity is spread across a full degree of sky, be sure to use your lowest-power eyepiece when searching for it. Even then it may evade you. The nebulosity is difficult to spot for several reasons. First, its huge size gives it a low surface brightness — its light is spread out so that individual parts of it appear dim. This demands the light-gathering ability of a large-aperture telescope. Adding to the problem are the relatively bright cluster stars: although none shine brighter than 8th magnitude, these stars turn into brilliant beacons when viewed through telescopes. The result is that glare can overpower your eye, rendering the nebula difficult to spot.

The nebula surrounding the cluster IC 1848 is another difficult test for backyard astronomers. Using the 13.1-inch reflector equipped with a 26mm Plossl eyepiece and a nebula filter, I observed a large, very faint, amorphous glow surrounding a fairly conspicuous star cluster. To my eye, the brightest section of nebulosity lies to the cluster's east. Like IC 1805, IC 1848 appears perfectly featureless and disappears from view without the filter in place. Look for it about 2.5° east of IC 1805 and about 4.5° north of Eta (η) Persei, the star at the tip of Perseus' head.

Now let's travel west to Gamma (γ) Cassiopeiae, the prototype for a class of rapidly rotating type-B variable stars. Marking the center of the constellation's W asterism, Gamma fluctuates erratically between magnitudes 1.6 and 3.0 and is associated with a pair of emission nebulae found 20' north and east of the star. These are designated **IC 59** and **IC 63**, respectively, and prove even more difficult to spy than either IC



IC 405 AND IC 410 can be found on opposite sides of a trapezium that includes 17, 18, and 19 Aurigae.

1805 or IC 1848. In photographs both IC 59 and IC 63 appear as fan-shaped glows; visually, each is seen as little more than an indistinct glow.

IC 63 is the easier of the two to find. A 13.1-inch scope provides a hint of the object's cometlike shape, but the cloud's extremely low surface brightness makes its form difficult to confirm. IC 59 is tougher still. I think I saw it as a dim, shapeless glow surrounding a semicircular group of stars that reminded me of a miniaturized Corona Borealis. Once again, without the nebula filter in place, both objects vanished.

Perseus is home to **NGC 1579**. Begin your search at 2nd magnitude Zeta (ζ) Persei. Scanning 6° east-northeast, keep watch for three 6th-magnitude stars lined up in a tight north-south row. From this point, NGC 1579 is about 2° northwest. Through medium-sized amateur instruments, NGC 1579 appears as a small, faint cloud set just north of the 12th-magnitude star that illuminates it. NGC 1579 does not show a definite form through amateur scopes. Instead, most observers note it as irregular or perhaps rectangular in appearance. Photographs reveal its full 12' by 8' dimensions, as well as the presence of subtle dark lanes.

Three more challenging nebulae can be found in central Auriga, each within 3° of the 4th-magnitude star Phi (π) Aurigae. Brightest of the group is the emission nebula **NGC 1931,** located a little less than 1° east of Phi. Through an 8-inch telescope, NGC 1931 appears as a small, oblong mist of greenish light surrounding three faint stars. Larger instruments more readily define the nebula's unique shape — some observers have likened it to a peanut — as well as add a fourth star to the central trio.

Due west of Phi Aurigae is the strange variable star AE Aurigae. Studies show that AE, which usually maintains 6th magnitude, is an escapee from the Orion complex of nebulosity. The star has apparently been speeding on its way for about 2.7 million years. Other probable runaways from Orion are 53 Arietis and Mu Columbae. The proper motion of all three can be traced back to a common point near Eta (η) Orionis.

Surrounding AE Aurigae is a large emission nebula catalogued as **IC 405** and popularly known as the Flaming Star Nebula. In long-exposure photographs, IC 405 displays a striking filamentary structure that undoubtedly led to its incendiary nickname. Even through the largest amateur telescopes, IC 405 appears as a grayish puff of smoke set near a kite-shaped stellar asterism (AE Aurigae marks the top of the kite). The association of the variable star and IC 405 is a fleeting one, as the star is traveling through space about three times as fast as the nebula. As AE Aurigae passes through and then beyond the cloud, IC 405 will revert to a dark nebula.

IC 405 and IC 410
Sizes 30' by 19' and 40' by 30' by Chuck Vaughn

The final complex of nebulosity in Auriga is the most difficult to spot. Engulfing the attractive open cluster NGC 1893, 2° southwest of Phi, is the large emission cloud **IC 410**. Although this object measures about 30' across, only a small portion of the nebula can be spotted visually. Look for a soft, irregular glow just northwest of the little cluster.

Bright nebulae offer great challenges to backyard astronomers, but when viewed through high-quality telescopes and under clear, dark skies, they are among the most rewarding. Don't have any reservations about searching for these challenging objects on a chilly winter night this year. Try your luck with these objects and they will not disappoint you. ☐

Phil Harrington is a frequent contributor to ASTRONOMY. His first book, Touring the Universe through Binoculars, *was recently published by John Wiley & Sons.*

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ASTROPHOTO OF THE MONTH

IC 405, "The Flaming Star Nebula," in Auriga. 45 minute exposure by Martin Germano using an 8" f/5 telescope with LUMICON 2" Newtonian EASY-GUIDER, and 2415 film hypersensitized in a LUMICON Model 300 Hyper-Kit. IC 405 is faint and is seen best visually with either a LUMICON UHCFilter, or preferably a LUMICON H-Beta Filter.

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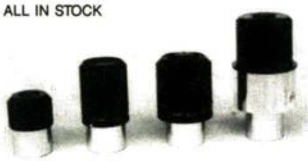

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Rich Zepernick, Cresskill, NJ

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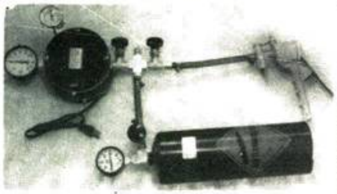

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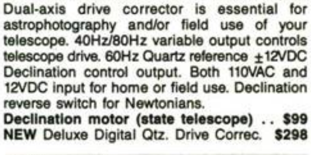

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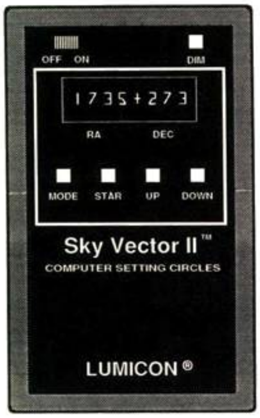

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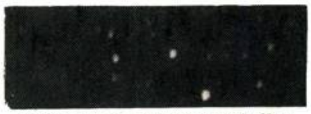

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COMET LEVY'S SKY SHOW

During August and September 1990 Comet Levy (1990c) brightened spectacularly and delighted observers everywhere. Discovered in late May by Arizona comet hunter David H. Levy, the comet reached naked-eye visibility by August.

"Finally we had a comet that didn't let us down," says Todd Lohvinenko, of Winnipeg, Manitoba, Canada. "For once the brightness predictions panned out and we were treated to a bright, naked-eye spectacle. I sketched the comet on the night of August 20 and estimated its magnitude at 6.0, based on observations of the nearby star 6 Equulei. At the time it was visible just southeast of the star Delta Equulei and appeared as a large, circular haze with a bright center."

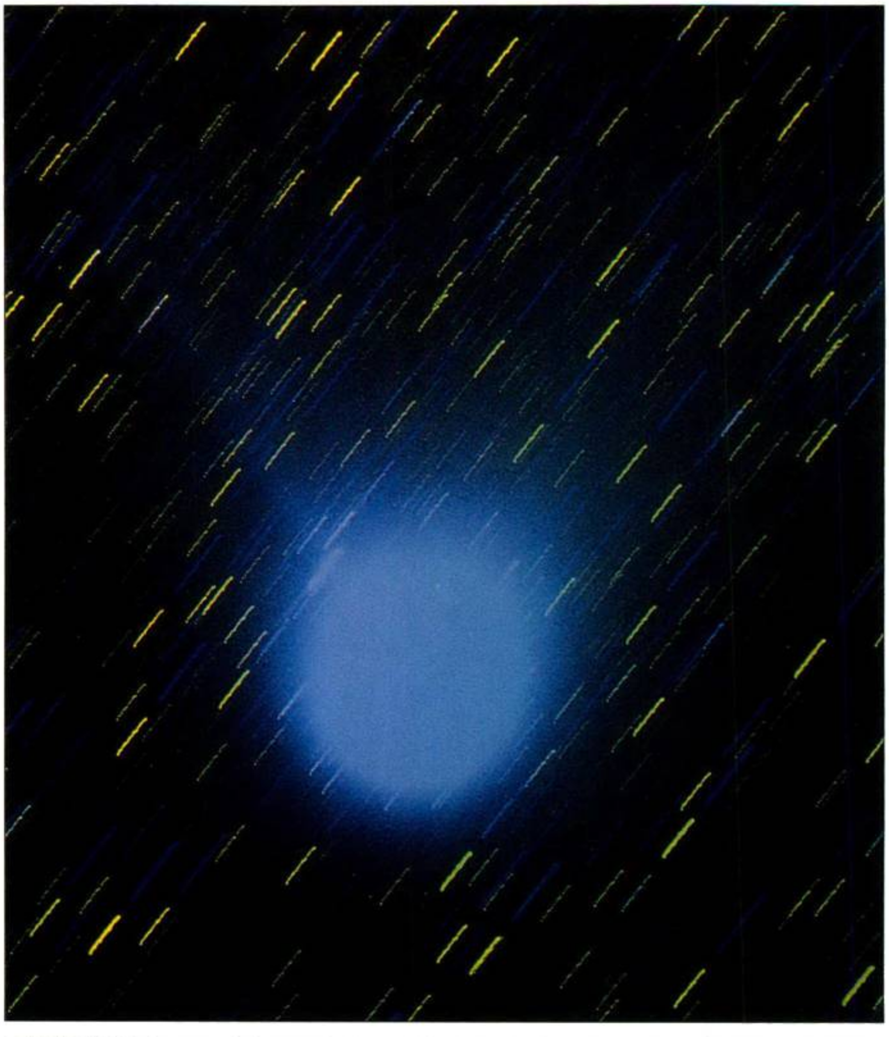
On August 15 Michael Boschat of Halifax, Nova Scotia, sketched the comet. "I found Comet Levy using averted vision and it appeared brighter than M13 and nearly as bright as M31, so I placed the comet at approximately 4th magnitude," says Boschat. "I didn't notice any tail when I observed the comet with my 2-inch refractor at 40x. However, the comet appeared elongated in position angle 48° and the nucleus appeared off-center."

Six nights later Boschat again observed Comet Levy. "This time I traveled 25 miles outside of Halifax," says Boschat. "On arriving at the dark-sky site, I immediately saw the comet below Delphinus. Using the constellation's stars, I estimated the comet's magnitude at 3.8, about the same as Alpha Delphini. With my 8x40 binoculars I detected a small, fan-shaped tail about 15' long. This comet was substantially better than Halley!"

Astrophotographer James R. Foster of Hollywood, California, viewed and photographed the comet from Mt. Pinos, California. "On August 20 many observers commented on how easy the comet was to see with the naked eye; its magnitude was then about 3, and it appeared to be approximately one-third to one-half the size of the Moon. It was a hell of a sight!"

A BIG, BRIGHT BALL of glowing plasma, Comet Levy reminded observers of 1983's IRAS-Araki-Alcock. Photo by Chris Schur.

SOFT, PINK GLOWS emanating from the nucleus marked Comet Levy's broad dust fan. Photo by Val Akins.



COMET LEVY shone at 3rd magnitude and developed a broad dust fan and thin gas tail during the last week of August 1990. Photo by Ronald E. Royer.

CLOSE FOCUS ON COPERNICUS

Those who try it know that lunar photography is no easy task. That's especially true when photographing details on the Moon, which requires an enormous image scale and a relatively long exposure. Christian Viladrich's high-resolution photograph of Copernicus nets this month's $100 "Best Astrophoto" award. A resident of Cahors, France, Viladrich used an 8-inch SCT at f/50 and hypersensitized Tech Pan film for the photo.

Shooting the Moon from a wider perspective was Chris Trounson's objective when he caught a conjunction between the Moon and Venus in October 1989 (bottom, left). Mars is the bright object at lower left in Mark Coco's all-sky exposure made on August 13, 1988 (bottom, right). Coco used an 8mm f/4 lens to capture the wide expanse of sky. Saturn, the most spectacular of all planets, was captured by Jean Dragesco in the spring of 1984 (below).

The recent increase in solar activity has generated interest in photographing aurorae like this one in Alaska, a spectacular event when photographed by Forrest Baldwin in 1982 (left).

A MAGICAL PAINTING ON THE SKY

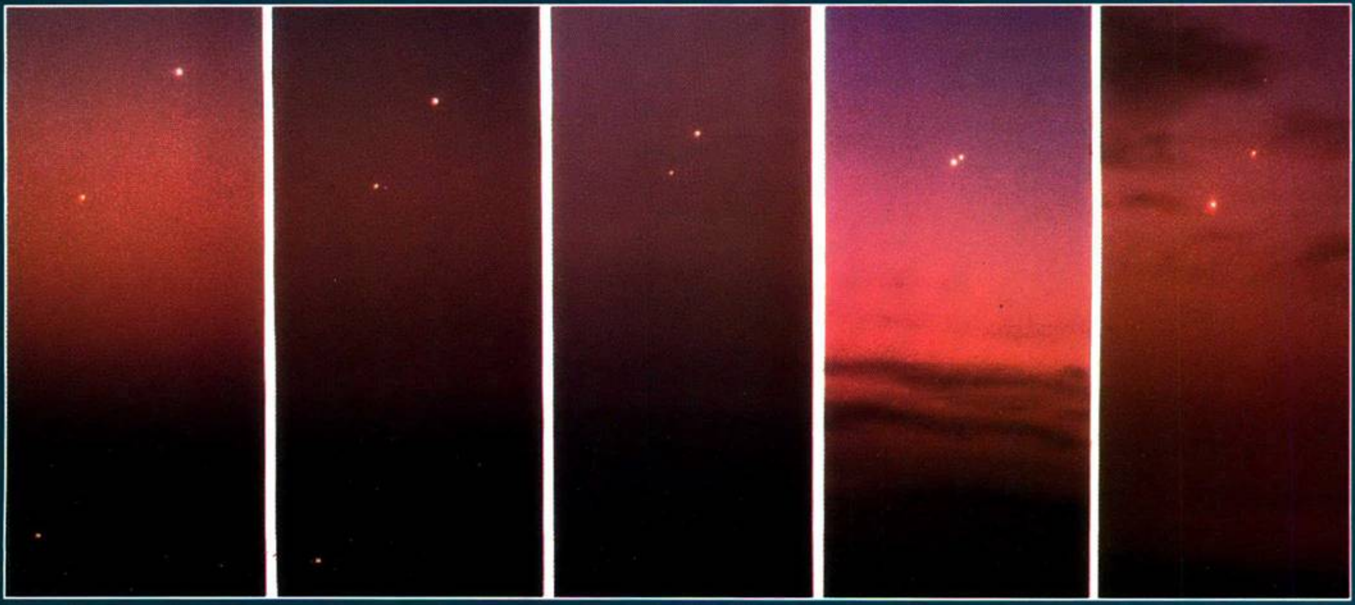
Michael Terezoni knew he had to capture on film the impressive auroral display he stood watching from Baxter State Park in northern Maine. It was August 23, 1990, and he had witnessed bright aurorae during the past four consecutive nights. "The shows started off as a mere glow and built into sheets of light with green rays and patchy curtains across much of the entire sky."

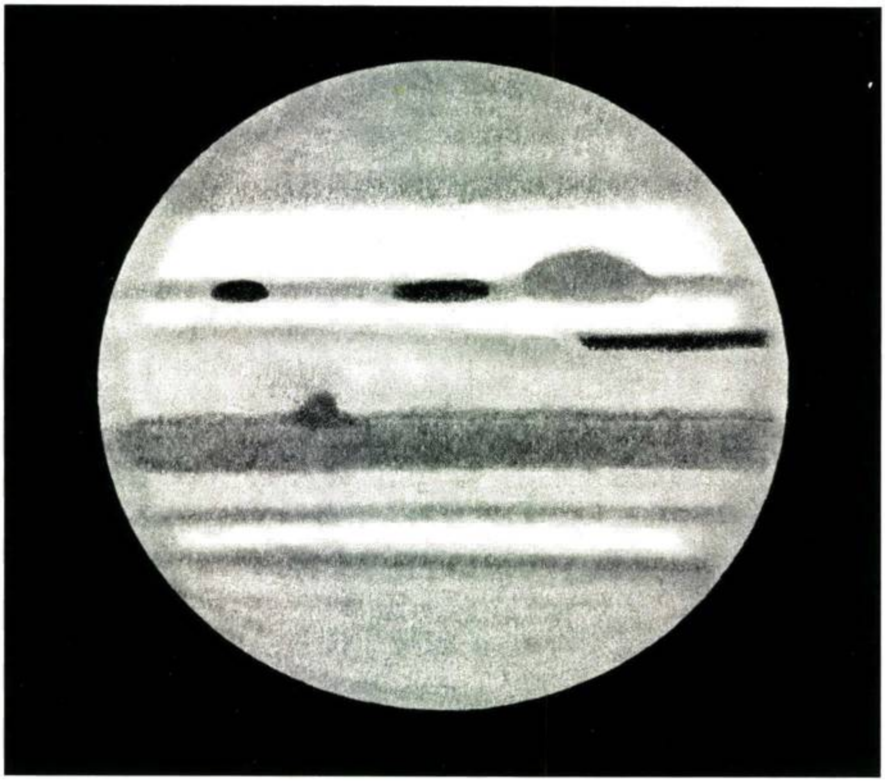
Terezoni asked one of the park rangers and a friend to pose for a 16-second exposure under the aurora. The resulting photo (far left) wins this month's $100 "Best Astrophoto" award. Terezoni mounted a camera fitted with a 28mm f/2.8 lens on a tripod and used Ektapress 1600 film.

Aside from Comet Levy, observers in August got a kick out of watching the slim crescent Moon slide in front of Jupiter and its moons. Dozens of astrophotographers recorded the occultation, but one of the prettiest shots we received was that made by Christopher Galfo of Auberry, California (opposite, bottom left). Galfo used a 14-inch SCT at f/7 and Konica 3200 film. Art Ciampi of Houston, Texas, recorded a closeup sequence of Jupiter slipping behind lunar mountains (left). Ciampi used an 8.8-inch Takahashi SCT for the exposures.

July 21's solar eclipse has not been forgotten: John R. Foster of Portland, Oregon, sent a telephoto shot of the event (opposite, bottom right). Foster used a 400mm lens at f/32 and Kodachrome 64 for the 1/500-second exposure.

Numerous astrophotographers documented the recent pairing of Jupiter and Venus in the morning sky. Fabrizio Melandri captured the two planets as they danced together over Voltana, Italy, between August 10 and 14, 1990 (below). Melandri used a 100mm f/3.6 lens, Ektachrome 200 film, and 6-second exposures.





HELLO, SOUTH EQUATORIAL BELT! After a 16-month-long disappearance, Jupiter's South Equatorial Belt darkened to prominence again last September. Jose Olivarez' sketch shows the planet as viewed with a 12-inch scope at 154x on September 3, 1990.

JUPITER'S DARKENING BANDS

"Jupiter is undergoing a remarkable burst of activity," according to Jose Olivarez, Jupiter Recorder for the Association of Lunar and Planetary Observers. "Ever since the planet reappeared in the morning sky, it has put on quite a show. The most fundamental change is that the planet's South Equatorial Belt is once again becoming visible, and other belts and bands are showing increased activity and detail."

On August 21 Olivarez observed the planet with a 12-inch reflector at 154x and noted "the northern half of the Great Red Spot looks faded and the South Equatorial Belt is dark and connected to the preceding end of the Red Spot. The two most prominent belts are the North Equatorial Belt and the North Temperate Belt."

Five nights later Olivarez recorded that "the South Equatorial Belt looked dark and gave the impression of being bluish in color." On August 30 he observed "the South Polar Region appears darker than the North Polar Region. The entire equatorial zone is dull and orangy in color." Such varied changes on Jupiter's cloudtops will surely attract observers for months to come. — *David J. Eicher.* □

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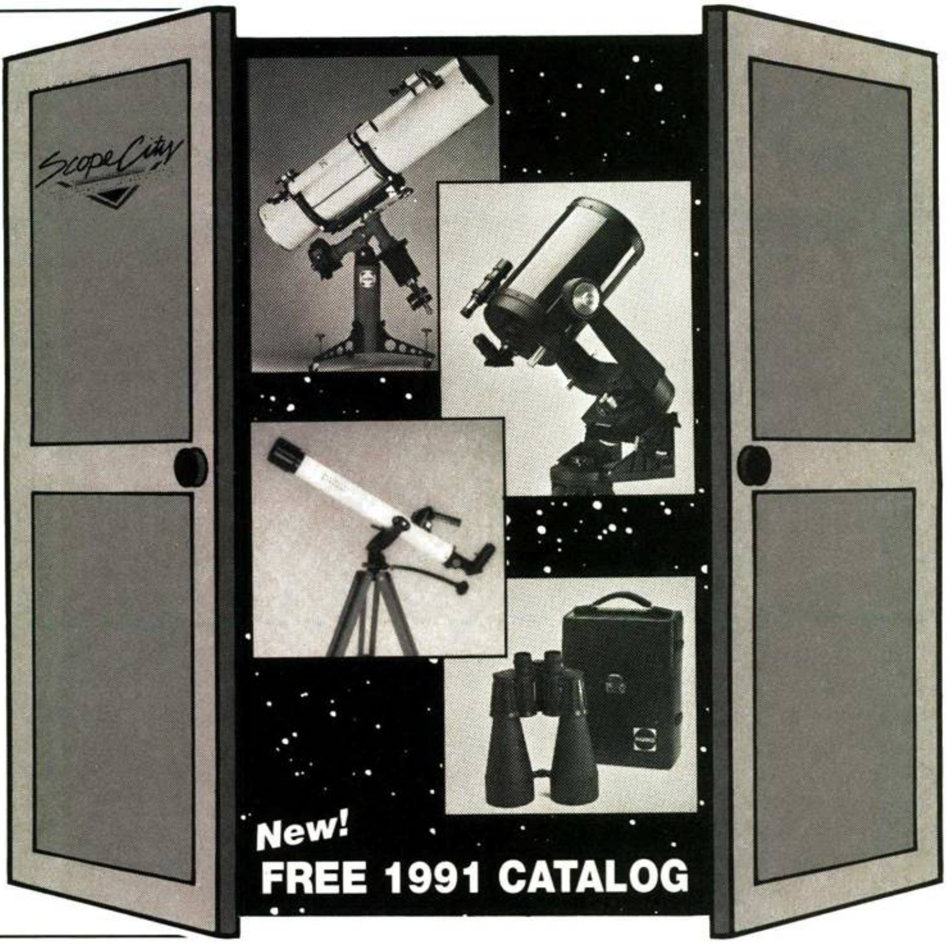

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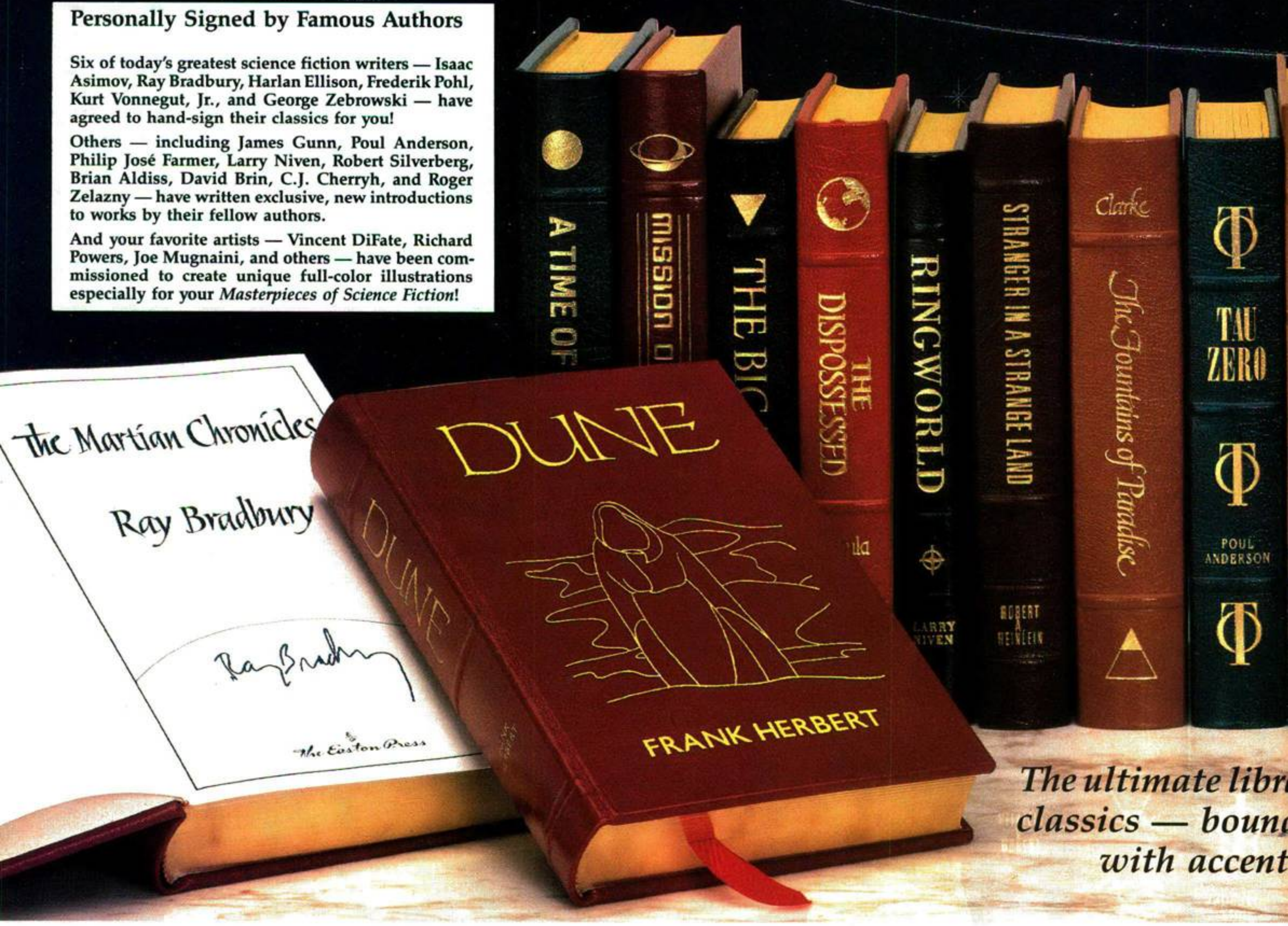
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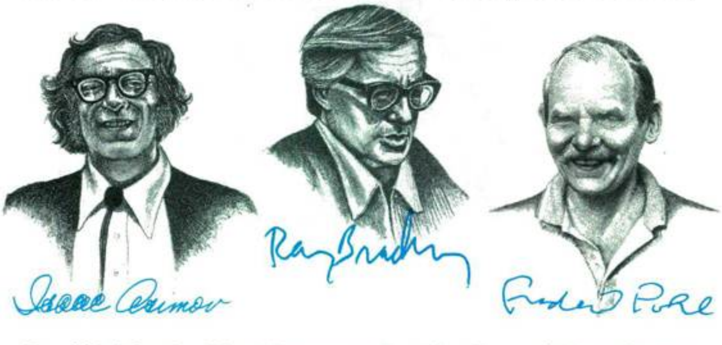
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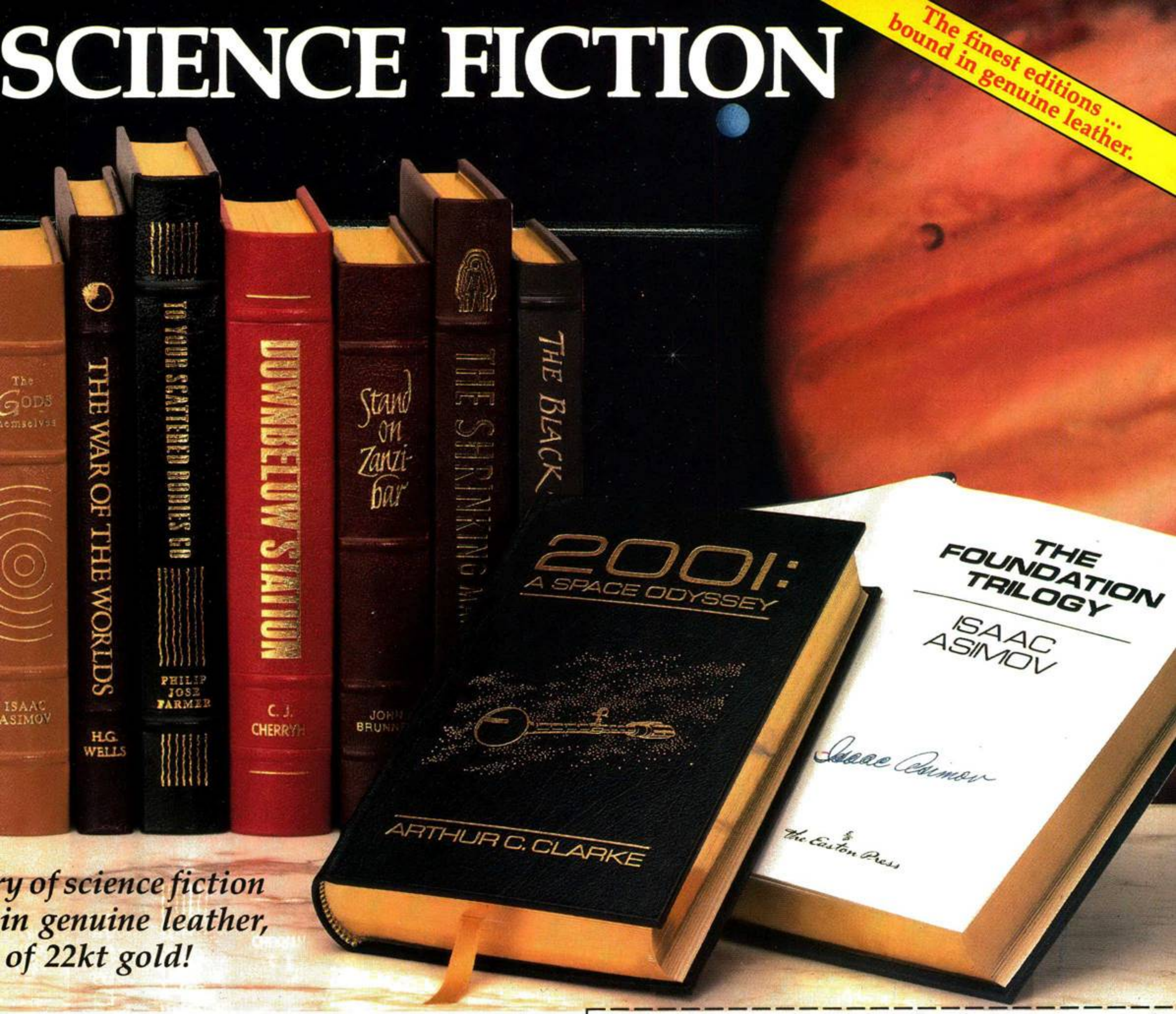
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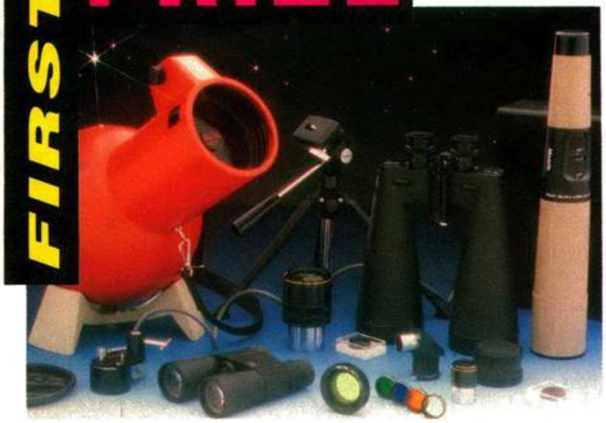

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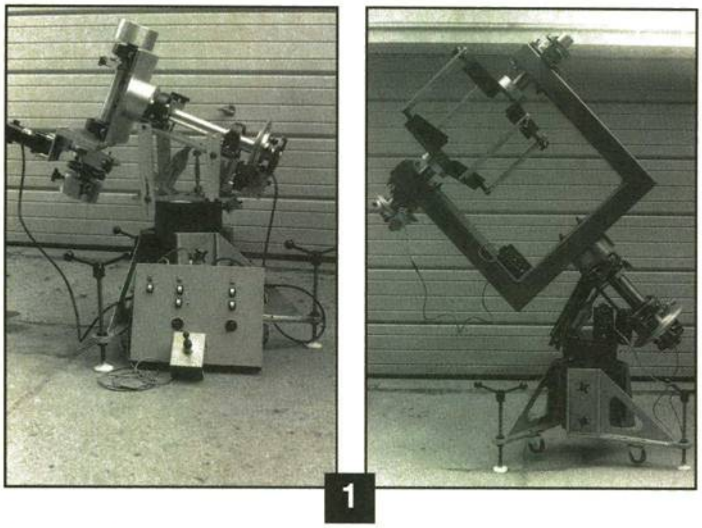

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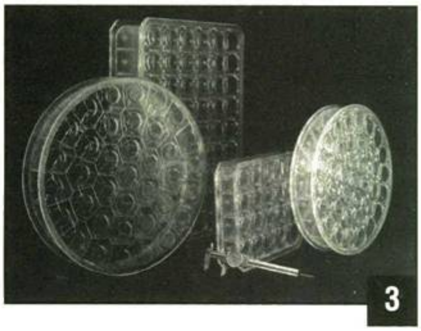

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ASTROPOINT II helps the user find astronomical objects by calculating precessed declinations and hour angles, as well as the altitudes and azimuths of objects, by updating them in real time. It can be used at the telescope to help users aim equatorial mounts equipped with conventional setting circles and Dobsonian mounts equipped with altitude and azimuth circles. *ASTROPOINT* is available for the Atari Portfolio, 520ST, 400, and 800 models, MS-DOS portable computers, IBM PCs and compatibles, and Apple IIe and IIc computers. Specify computer and disk format (3.5 or 5.25-inch).

ASTROPOINT II, Dale C. Ferguson, 22341 Sprague Road, Strongsville, OH 44136; $19.95 plus $1.25 shipping.

5

Galilea Lunar Clock

This new clock follows the lunar phases by means of the constant movement of a black hemisphere that revolves around a photo of the Moon's surface. The clock also has a standard clock face and shows the month and day. It is powered by a single AA battery (included) and comes with a 6-month warranty.

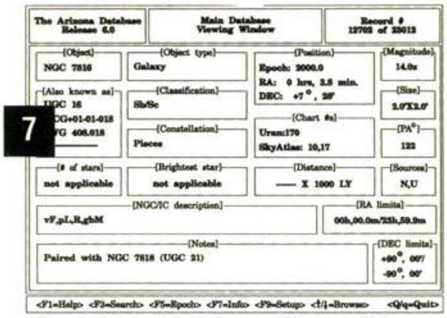
PD Unique Products, 484 Lighthouse Avenue, Suite #104, Monterey, CA 93940. (800) 877-4PDU. $69.95 plus $5 shipping and handling. Allow 4 to 6 weeks for delivery.

6

SuperStar and SuperStar Professional

The new versions of both these astronomy software programs now support the Hubble Guide Star Catalogue, allowing the user to read data from the Hubble CD-ROM Catalogue disk (not included). *SuperStar* then displays the charts derived from this data on screen. This extends the database of *SuperStar* to some 19,000,000 objects. Other third-party databases, such as the floppy disk version of the *NGC 2000.0,* are also supported. *SuperStar* normally comes with a database of 259,000 stars from the SAO Catalogue and over 8,000 deep-sky objects. The positions of the planets and other solar system objects are also calculated for display or printing. The Professional version supports higher precision star positions with proper motion, importing scanned pictures into the database and calculation of orbits from positions. *SuperStar* requires an IBM-PC or compatible with DOS 2.11 or higher. A hard disk, math coprocessor, and a mouse are recommended.

Picoscience, 41512 Chadbourne Drive, Fremont, CA 94539; (415) 498-1095. SuperStar: $149.95; SuperStar Professional: $249.95.


7

The Arizona Database
Release 6.0

Main Database
Viewing Window

Record #
12702 of 23013

[Object]
NGC 7816

[Object type]
Galaxy

[Position]
Epoch: 2000.0
RA: 0 hrs, 3.8 min.
DEC: +7 °, 28'

[Magnitude]
14.0z

[Also known as]
UGC 16
CG+01-01-018
VG 408.018

[Classification]
Sb/Sc

[Size]
2.0'X2.0'

[Constellation]
Pisces

[Chart #s]
Uran:170
SkyAtlas: 10,17

[PA°]
122

[# of stars]
not applicable

[Brightest star]
not applicable

[Distance]
—— X 1000 LY

[Sources]
N,U

[NGC/IC description]
vF,pL,R,gbM

[RA limits]
00h,00.0m/23h,59.9m

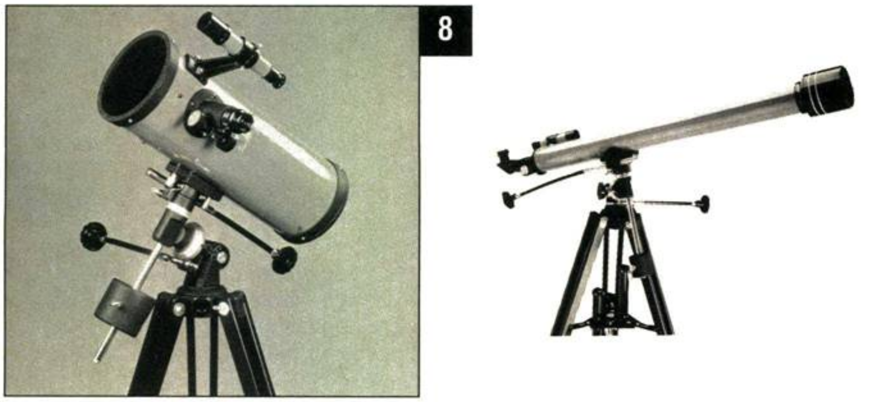
[Notes]
Paired with NGC 7818 (UGC 21)

[DEC limits]
+90°, 00'/
-90°, 00'

The Arizona Database, Version 6.0

The *Arizona Database,* Release 6.0, and AZVUE, Version 2.0, are a bundled software package for IBM XT, AT, or compatible computers with a hard disk drive. The Database contains information on 23,000 deep-sky objects referencing over 43,000 object designations compiled over a three-year period from hundreds of sources. Each object record contains the object's catalogue designations, its constellation, type, epoch 2000.0 coordinates, magnitude, size, position angle of major axis, distance, the *Uranometria* and *Sky Atlas* chart numbers, as well as the original NGC/IC description. The AZVUE program allows the user to search through the database using various criteria, including by *Uranometria* chart number.

The Arizona Database Project, Inc., 3135 South 4th Street, Suite #3, Tempe, AZ 85282. $89.95.


8

Two New Tasco Telescopes

Tasco announces two new telescopes suitable for the beginning amateur. The model 911TR is a 4.5-inch f/5 reflector on an equatorial mount with slow motion controls and wooden tripod. Compared to many other 4.5-inch reflector models, the 911TR's fast focal ratio yields a wider field of view in a compact, portable package. The Model 675TR is a new 60mm aperture refracting telescope, with an equatorial mount, slow-motion controls, wood tripod, 6x20 finderscope, Sun projection screen, and Moon filter.

Tasco Telescopes, P.O. Box 520080, Miami, FL 33152-0080. Model 911TR: $344; Model 675TR: $296. ☐

This department presents new product announcements issued by their manufacturers. The product information is as supplied by the manufacturers or distributors. All prices are suggested retail. Suppliers are invited to send their product announcements to the attention of Alan Dyer.

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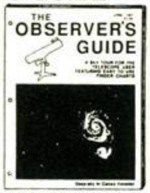

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A USEFUL BINOCULAR MOUNT

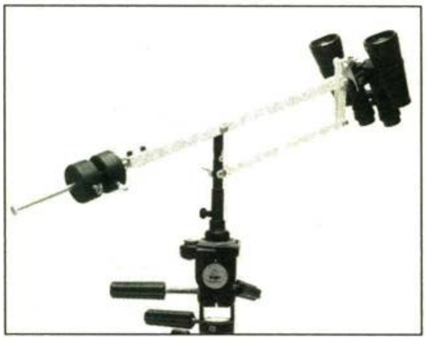
Vista Binocular Guider, (Vista Instrument Corporation, Santa Maria, CA 93456; (805) 922-2545), list price: $130.00.

Binoculars are surely the most underrated and underused optical instruments for astronomy. Beginners dismiss binoculars, thinking that "serious" astronomy requires a telescope, while veteran observers often feel binoculars are just for beginners! One of the problems with using a binocular for astronomy is that you simply can't hold it steady enough to really study the sky through it. You can, of course, buy an adapter to mount your binocular on a tripod. This improves the steadiness of the view but the combination is extremely uncomfortable to use — you can't get underneath the binocular when it's on the tripod when trying to observe high overhead. The solution is a cantilevered binocular holder like Vista Instruments, "Binocular Guider."

The seven pound Vista Guider threads onto the top of your tripod. (We suggest using a very solid tripod, not some lightweight $50 job.) The extra height and overhang of the Guider allow you to get under the binocular when looking overhead. The Guider consists of a pivoting arm that can swing up and down and through a 360° rotation. Counterweights at one end balance the binocular at the other. The unit we reviewed is capable of handling binoculars up to the popular 70mm and 80mm models, though their weight taxes the steadiness and the friction-damped motions of the Vista Guider. I found that the Guider works best with lighter weight 7- to 10-power 50mm binoculars. To use the Vista Guider, your binocular must have a 1/4-20 tripod mounting hole or have a tripod clamp or bracket of some kind.

Using the Guider is very straightforward. The altitude motion is accomplished by tilting the small pivoting platform that the binocular attaches to at the end of the Guider's arm. This axis is simply a friction joint whose stiffness is adjusted by tightening a wing nut to squeeze the joint together. However, when it is tight enough to prevent the binocular from flopping down under its own weight, it then becomes a little too stiff to move smoothly. Moving the binocular by a few degrees up or down takes a few attempts, as the stiff movement makes you jerk the binocular first too far one way then too far back the other. On the other hand, the azimuth motion of the Guider is a little too free; it has a lock knob on the azimuth axis but this doesn't tighten quite enough for my taste.

The swing motion that moves the whole arm up and down works well; it is for changing the eye height of the binocular. As you move the Guider through this motion, the binocular actually stays aimed at the same point in the sky. This is very handy for accommodating the different heights of observers at star parties or for family viewing sessions. The adjustable height also helps you find the best position no matter how high in the sky you are looking.



THE VISTA BINOCULAR GUIDER swings up and down for the most comfortable viewing height.

I encountered a problem when I tried to attach a binocular that uses the type of tripod adapter that clamps around the central focus rod. With this arrangement, it was impossible to look through the binocular when it was aimed at the zenith — your nose hits the end of the cantilevered arm. The solution was detaching the end platform that the binocular screws to and flipping it around 180°. Binoculars that attach using a threaded hole at the front of the bridge shouldn't have this problem.

Despite the lack of silky-smooth motions, the Vista Guider works very well. It holds binoculars steady and is a great improvement in convenience over a standard tripod. For those that already have $300 to $500 or more invested in a top-quality binocular, the $130 cost of the Vista Guider is a reasonable price for making your binocular a useful observing tool. — *Alan Dyer* ☐

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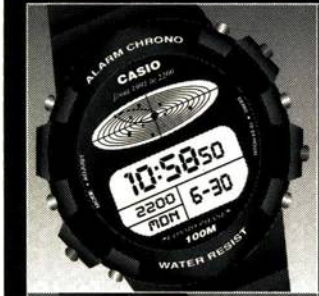

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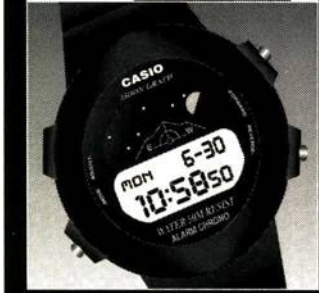

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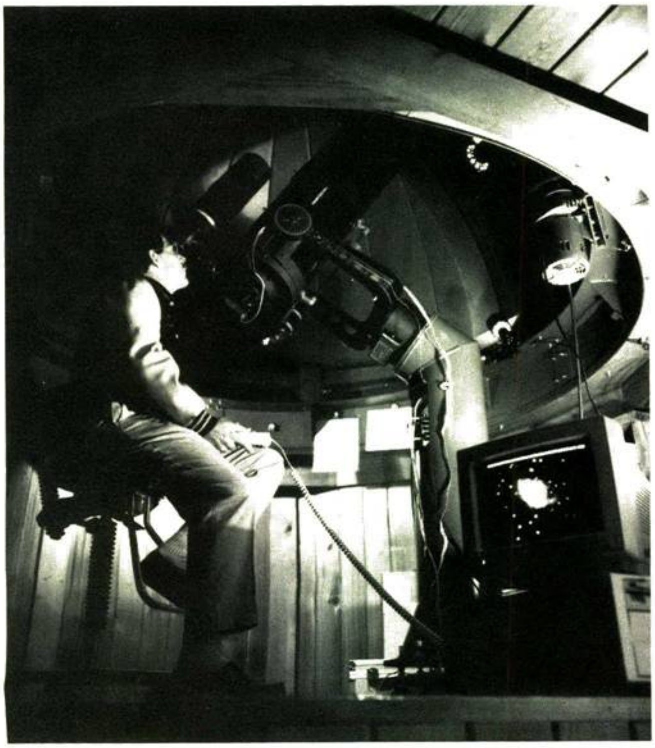

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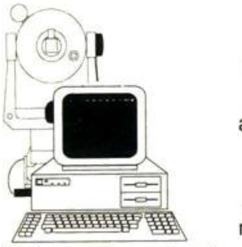

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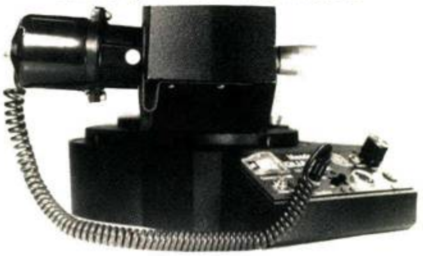

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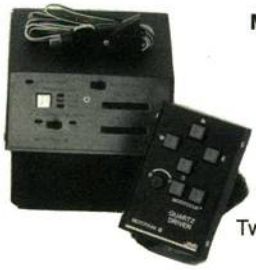

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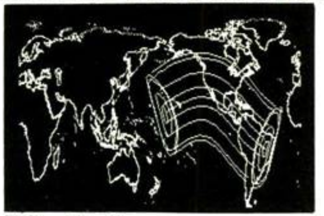

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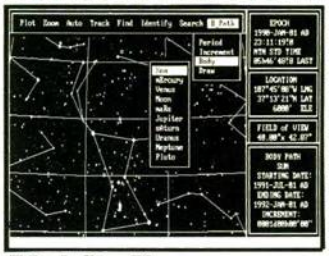

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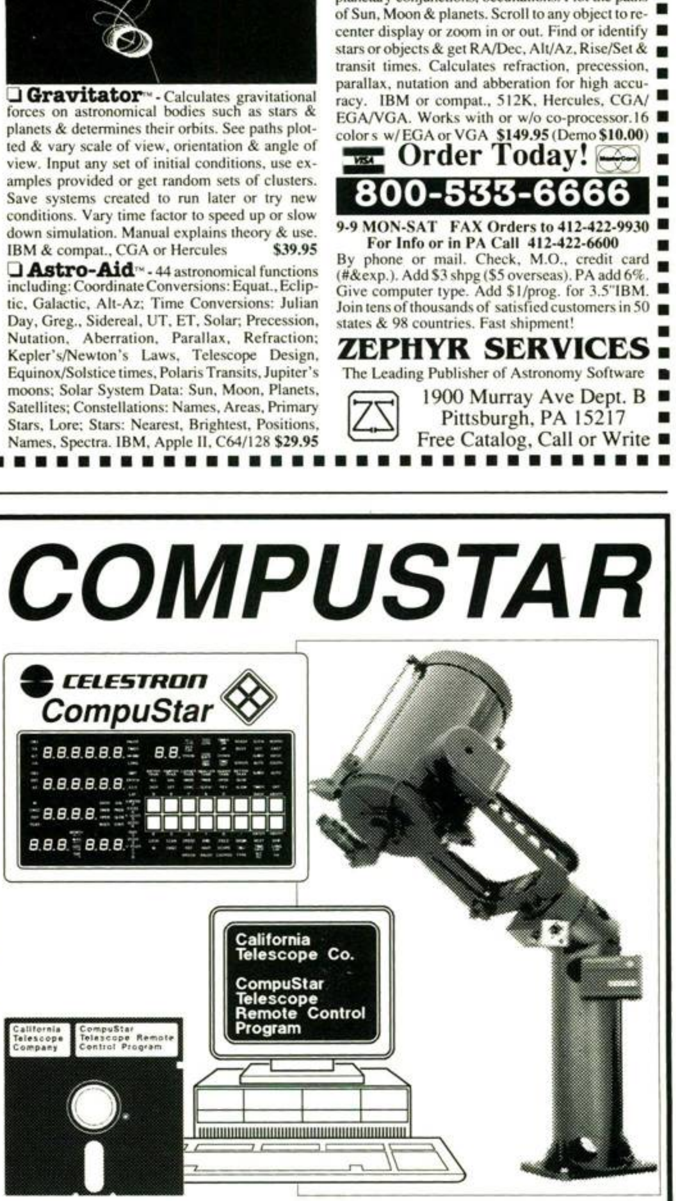
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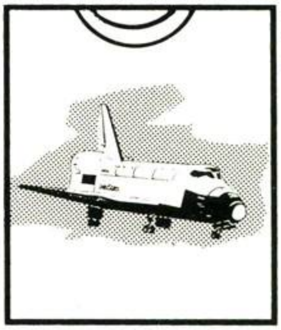

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Astronomy Books

NIGHT SKY TEACHING HELP

Exploring the Sky: 100 Projects for Beginning Astronomers, by Richard Moeschl, (Chicago Review Press, 1989), ISBN 1-55652-039-5, 339 pages, paperback, $14.95.

Richard Moeschl is a teacher who found there was very little practical astronomy material for classroom instruction for students in middle schools. He decided to do something about it and the result is *Exploring the Sky.* Besides being a great resource for classroom use, Moeschl's book is also useful as a self-help guide for those wanting to learn more about astronomy. The backbone of the text is 100 simple experiments. The 11 1/2" by 14" soft-backed book has no color plates but lots of drawings, photographs, charts, and other graphics.

Exploring the Sky is broken down into seven chapters, starting with experiments designed to introduce you to the sky and how it moves and then progressing into higher order topics like measuring distances on the sky, exploring the Earth, the tools used in astronomy, and a section on space travel.

The author wanted something much more than a list of 100 projects. So to make the book useful to the teacher and more pleasant to read, he introduces each project and explains many topics relating to the experiment. Some of these include the history surrounding the experiment, reasons and ideas for doing it, ample background information, and even relevant literature or poetry.

Unlike traditional astronomy texts, Moeschl's projects often range into topics not directly related to astronomy. Examples include several experiments that deal with life sciences and the balance of Earth's ecosystem. This section seems intended to send a strong environmental message to young readers and experimenters.

Projects in the book range from the very simple to fairly complex — from a star dome made from half of a tennis ball to a year-long experiment to show the analemma, and from the construction of simple refracting telescopes to a simple homemade jet turbine. Few of the experiments have much math involved in them, but all depend on close observation on the part of the student to understand the purpose of the experiment. Each experiment is followed by at least one question that asks the experimenter to tie the observed results to what was discussed in the text.

I found some of the directions for the projects a little vague at times, especially the more complex ones, but many of the instructions would have to be altered anyway, depending upon the exact materials used. However, each experiment has at least one line drawing that shows the set-up. These drawings work; they often explain the ideas behind the experiment much more quickly and clearly than any list of directions ever could.

The text in between the experiments touches on almost every possible topic even slightly related to astronomy. These are informative and entertaining to read, but the price of touching on so many topics is that the text is sometimes choppy and the subject matter seems to jump hurriedly from one subject to the next. It seemed as if the author (a teacher) wrote it for other teachers — so really it shines best as a teacher's guide.

Exploring the Sky also includes several appendices, called "Sky Files," which are very useful. These include graphs and charts used in experiments, lists of the Greek alphabet and mythological gods, constellation maps (with and without constellation lines), tables comparing the sizes of the planets, and a somewhat mixed-up Messier list that is printed out of order. The Sky Files could also prove useful to astronomy clubs that either have junior organizations or give programs to young children.

A two-page listing of where to find materials for the experiments is not very complete and looks like a last-minute add-on. Several ingredients for experiments that were not in the listing left me wondering where I might find them — or, in some cases, even what they were.

Anyway, for the middle or junior high school teacher teaching an astronomy class for students with little math or science background, this book would be a tremendous resource. I also recommend it to parents who would like to spark their children's interest in how the world works with easy and interesting hands-on experiments.

— *Robert Bunge*

QUICK PICKS

Reference Works

Encyclopedia of Astronomy and Astrophysics, edited by Robert A. Meyers and Steven N. Shore, (Academic Press, 1989), ISBN 0-12-226690-0, 807 pages, hardcover, $49.95.

This one-volume encyclopedia sets out to offer "a comprehensive, in-depth, and yet concise treatment of the latest in fundamental astronomy and astrophysics theory, instrumentation, and observations of the solar system, stars, and stellar systems." It is also intended to reach an audience that ranges from the proverbial intelligent lay reader to the professional astronomer. To a large extent it succeeds in both aims.

Each chapter begins with an outline of its contents and a glossary of special terms used within it. The chapter titles reflect their original use in this book's parent work, the *Encyclopedia of Physical Science and Technology,* so you find mixed usages such as "Lunar Rocks" and "Moon (Astronomy)." Also, each article emphasizes only the physics aspects of its subject. For example, "Meteorites, Cosmic Ray Record" covers that subject alone and includes nothing else on meteorites, such as mineralogy.

With entries arranged alphabetically, no encyclopedia is designed for smooth reading, but the publishers could have avoided a certain amount of dictionary-jolt. Instead of one alphabetical run, I might have argued for an alphabetical listing within subgroups (for example, solar, planetary, general astrophysics, etc.). In any case, the 25-page, triple-column index gets you into the articles easily, no matter what subject heading you have in mind.

I was astonished at how little mathematics the book contains; it's unlikely that any interested layman would find much to stumble over in what is there. Concepts, however, are presented succinctly, so the text repays a careful reading. Is this a book for you? Its $50 price isn't cheap, but the book offers very solid value for the money. I would judge this a very handy reference work for any dedicated amateur astronomer.
Robert Burnham

Space

The Space Telescope, by Robert W. Smith, (Cambridge University Press, 1989), ISBN 0-521-26634-3, 478 pages, hardcover, $39.50.

Subtitled "A study of NASA, science, technology, and politics," this work is an institutional history of the massive development project that culminated in the *Hubble Space Telescope.* Written before launch, the book of course has nothing about the optical problem, and the sections on Perkin-Elmer's fabrication of the primary mirror offer no clue, even with hindsight, that anything was amiss. Still, this is the most complete book yet on the history of *Hubble.* ☐

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February 14-18
7th Annual Winter Star Party, Florida Keys, Florida. Contact: Bob or Sharon Grant, 5401 Southwest 110th Avenue, Miami, FL 33165. Phone: (305) 595-8778.

March 30
Astrophoto IX, Thousand Oaks, California. Sponsored by the Ventura County Astronomical Society. Contact: VCAS/Astrophoto IX, P. O. Box 982, Simi Valley, CA 93062.

April 20
Astronomy Day. Contact: Gary Tomlinson, Astronomy Day Coordinator, c/o Chaffee Planetarium, 54 Jefferson SE, Grand Rapids, MI 49503. Phone: (616) 456-3987.

July 8-12
Research Amateur Astronomy Symposium, La Paz, Baja California Sur, Mexico. Contact: Corporation for Research Amateur Astronomy, P.O. Box 16542, San Francisco, CA 94116. ☐

Please submit announcements at least four months before the date of the meeting or event.

When you write to organizations listed in Meetings and Events, include a self-addressed, legal-sized envelope with your request for information.

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WANTED — *Beyond Tomorrow: The Next Fifty Years in Space,* published in the early 1960s? Any condition or clear photocopy. R.J. Kirkland, 15212-84 Avenue, Edmonton, Alberta, Canada T5R 3X8.

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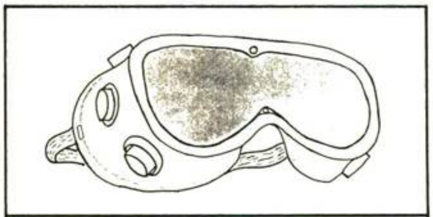

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Readings and Resources

Tycho Brahe (page 28)
Tycho Brahe; a Picture of Scientific Life and Work in the Sixteenth Century by John L. E. Dreyer (Peter Smith, 1977).

Voyages to the Worlds of Ice (page 42)
Planets Beyond by Mark Littmann, (John Wiley & Sons, Ltd., 1990). An excellent summary of what we know about the outer planets, how we learned it, and what we hope to learn in the future.

Magellan (page 48)
"Venus Unveiled," by Stephen D. Wall, ASTRONOMY, April 1989. Describes *Magellan* spacecraft and mission.

"Does Venus Have Active Volcanos?" by Larry Esposito, ASTRONOMY, July 1990. Looks at an intriguing interesting — and open — possibility.

Lunar Volcanos *(page 62)*
The Geologic History of the Moon, by Don E. Wilhelms, (U. S. Geological Survey Professional Paper #1348, 1987). A lengthy and profusely illustrated guide to lunar geology.

Lynxx-PC and SBIG ST-4 (page 67)
"CCD Cameras: Digital Astrophotography is Here," by Michael Chibnik, October 1990 ASTRONOMY. An introduction to CCDs and CCD terminology; the sidebar "How to Talk CCD" is a glossary of terms that may be helpful in understanding this review.

Observe the Geminids (page 72)
Observe: Meteors by David Levy and Stephen Edberg, (Astronomical League, 1986). A small but comprehensive booklet that details how to make and report useful meteor observations. Available from the Astronomical League, Science Service Building, 1719 N. Street NW, Washington, D.C. 20036.

CREDITS

Cover: NASA/STScI; *p. 4:* Dale Lightfoot, 28mm at f/2.8, Ektachrome 400, 4-hour exposure, August 12, 1985; *p. 22, top:* NASA image; *bottom:* NASA image; *p. 24:* NASA/Ames Research Center; *p.26:* Alan Dyer; *pp. 28-29 and 30-31:* illustrations by Bruce Bond; *p. 30 and 31, top:* courtesy William J. McPeak; *pp. 32-33:* illustration by Bruce Bond; *p. 32 and 33, top:* courtesy William J. McPeak; *pp. 34-35:* illustration by Bruce Bond; *p. 34 top:* courtesy William J. McPeak; *p. 35 top left:* NASA/Einstein Observatory; *p. 35 top right:* courtesy William J. McPeak; *pp. 36-37: NASA; pp. 38-39;* Tom Tracy; *p. 38:* Jupiter image courtesy NASA; *pp. 40:* Design Photographers International; *p. 40, top:* solar eclipse image by Fred Espenak; *p. 41, sidebar:* The Stock Market; *pp. 42-43:* illustration by Michael Carroll; *p. 44-45:* NASA; *p.46:* illustration by Michael Carroll; *p. 48, A:* U. S. Geological Survey, Flagstaff; *p. 48, B:* Arecibo Observatory, National Astronomy and Ionosphere Center; *p. 48, C:* NASA/JPL; *p. 49, D and E:* NASA/JPL; *p. 54:* Michael Searle, taken with a 50mm lens at f/2.8 and a 15-minute exposure on Ektachrome 400 film; *p. 57:* Mars map courtesy Jeff Beish; *p. 59:* Mira star chart reproduced by permission of AAVSO; *p. 63, left:* Jean Dragesco, 14-inch SCT, 2 seconds on Ilford XP400 at f/40; *right:* Christian Arsidi, 12-inch Cassegrain, 1.5 seconds on Tech Pan at f/48, September 1986; *p. 65, left:* Jean Dragesco, 14-inch SCT, November 17, 1980; *right:* Jean Dragesco, 14-inch SCT, Ektachrome, May 24, 1984; *p. 66, right:* Jean Dragesco, 14-inch SCT, 2 seconds on Tech Pan at f/40, November 19, 1980; *pp. 67-68:* product photographs by Chris Becker; *p. 69, top:* Orion Nebula by Richard Berry, Lynxx-PC on a 6-inch f/5 Newtonian reflector, composite of three exposures of 200, 15, and 2 seconds, August 30; *bottom:* Moon image by Richard Berry, Lynxx-PC on a Meade 2045 4-inch f/10 SCT, 0.01-second exposure, August 28; *p. 70:* M13 CCD images by Richard Berry, SBIG ST-4 on a 6-inch f/5 Newtonian reflector, 200-second exposure, July 24; M31, same as M13, August 25. CCD images reproduced by direct transfer of digital data into ASTRONOMY's page-makeup software; *pp. 72-73:* illustration by Bruce Bond; *p. 74:* Jerry Schad, 85mm f/1.4, Ektachrome P800/1600 at ISO 1600, 3-minute exposure, Dec. 12, 1988; diagrams by Patti Keipe; *p. 75:* diagrams by Patti Keipe based on art by Philip Bagnall; *p. 76:* Jack Newton, 20-inch f/5 reflector, Konica 3200 film, light pollution filter, 20-minute exposure; *p. 77:* Mace Hooley, 8-inch f/1.5 Schmidt camera, hypered Tech Pan film, #92 filter, 30-minute exposure; *p. 78, top:* Martin C. Germano, 8-inch f/5 reflector, hypered Tech Pan film, 45-minute exposure; *bottom:* Martin C. Germano, 8-inch f/5 reflector, hypered Tech Pan film, 50-minute exposure; *p. 79:* Chuck Vaughn, 180mm f/2.8 lens, H-alpha filter, 60-minute exposure; *p. 83, top left:* Chris Schur, 14-inch f/5 reflector, hypered Tech Pan film, 23-minute exposure on August 21, 1990; *bottom left:* Val Akins, 5-inch f/5.3 refractor, Fujichrome Super HG 400 film, August 25, 1990; *right:* Ronald E. Royer, 18-inch f/7 reflector, two color composites made with two negatives, August 23, 1990; *pp. 84-85:* Michael Terenzoni, 28mm f/2.8 lens, Ektapress 1600 film, 16-second exposure on August 23, 1990; *p. 84, bottom left:* Christopher Galfo, 14-inch SCT at f/7, Konica 3200 film, August 18, 1990; *bottom right:* John R. Foster, 400mm lens at f/32, Kodachrome 64 film, 1/500-second exposure on July 21, 1990; *p. 85, top:* Art Ciampi, Takahashi 8.8-inch SCT, August 18, 1990; *bottom:* Fabrizio Melandri, 100mm f/3.6 lens, Ektachrome 200 film, 6-second exposures on August 10, 11, 12, 13, and 14, 1990; *p. 86:* Jose Olivarez, 12-inch reflector at 154x and 190x on September 3, 1990.

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Advertisers

November 1990

Advertiser	Page
Adorama	100, 101
Advance Camera	91
Andromeda Software Inc	96
Applied Research & Consulting	10
ASM, Inc	95
Astro Cards	92
Astro-Link	13
Astronomics	50
ASTRONOMY Products	21A, 21B
Ball Photo	91
Bethany Trading Co	27A
Caledonian Graphics	92
California Telescope Co	94
Carlson Travel Network	99
Celestron International	15, 104
Centripoint	27A
City Camera	50
Coulter Optical, Inc	12
Cygnus-Graphic	51
Deen Publications	20
Denny's Astro Mart	16
EARTH Magazine	17
Easton Press	87A, 87B
Edmund Scientific Company	16
ELECTRIM Corporation	95
F.C. Meichsner Co	93
Focus Camera	98, 99
Fujinon	27A
Furnam University	16
Future Trends Software	103
Himalaya	16
Hypertronics	8
Innovative Energies, Inc	92
International Dark-Sky Association	10
Jim's Mobile Industries	93B
Los Angeles Optical Co	50
Lumicon	80, 81
Meade Instruments Corporation	2-3
Minolta	20
National Camera Exchange, Inc	18, 27A
Novagraphics	51
Orion Telescope Center	23, 25, 27, 27A
Parks Optical	86
Pauli's Wholesale Optics	82
P-D Unique Products	102
Robert A. Haag — Meteorites	27A
Rose Star Products	99
Santa Anita Camera Shop	96
Santa Barbara Instrument Group	93A
Science & Art Products	8
Scope City	87
Shutan Camera & Video	14
Skywatcher Videos	93
Space Ventures	21
Spectra Astro-Systems	20
SpectraSource Instruments	95
Stan Polczyk	27A
Starlight Telepictures	27A
Swift Instruments	51
Tele-Vue Optics, Inc	7, 9, 11
Texas Nautical Repair Co	97
Tuthill, Roger W., Inc	8, 91, 93
Unitron	102
Vantage Press	27A
Visual Vacations	18
Wholesale Optics of Penn	87
Wilsec	27A
Z2 Computer Solutions	96
Zephyr Services	94

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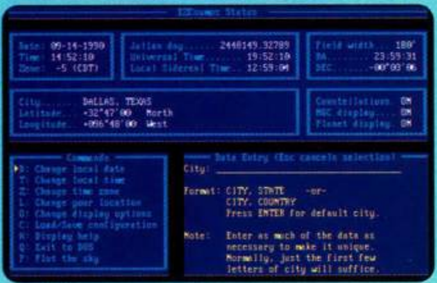

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Date: 09-14-1990   Julian day...... 2448149.32789   Field width... 180°
Time: 14:52:10     Universal Time......  19:52:10   RA........ 23:59:31
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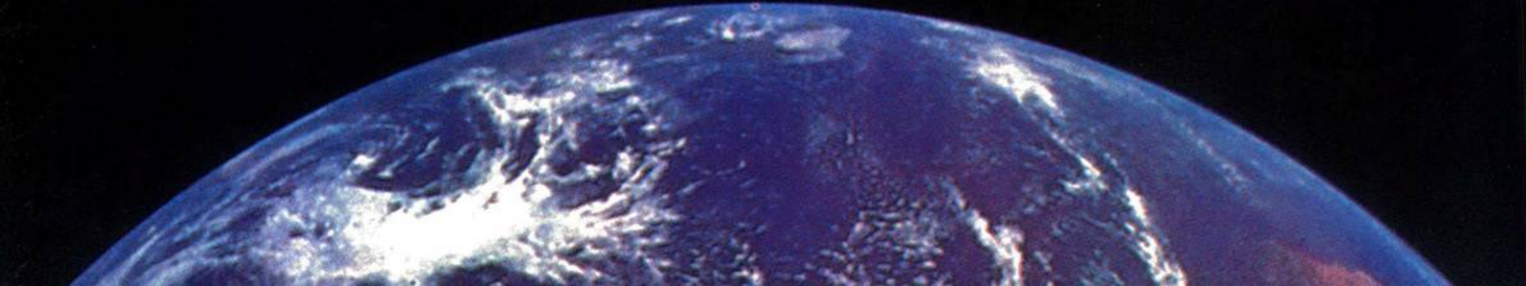
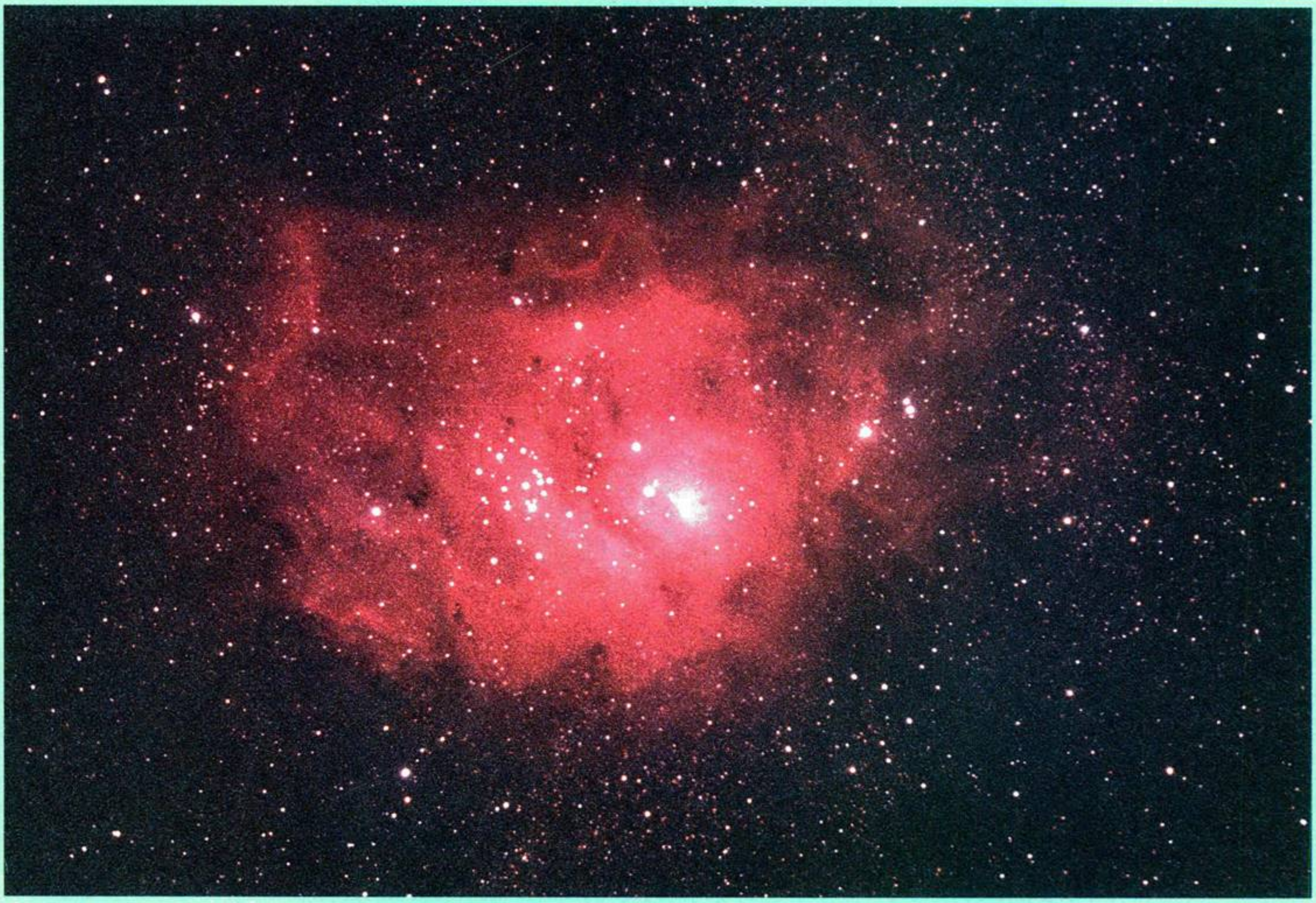


f/6.3 From CELESTRON???



C8 *Photo* *Lagoon Nebula* (M8) 30 *Minutes with* f/6.3 *Accessory* (*Jim Riffle, Astro Works*)

Yes, and not a simple chore. After almost four years of product development and refining by optical and mechanical engineers, we have achieved the desired results.

It would have been easy to make a dedicated f/6.3 Schmidt-Cassegrain (like other manufacturers). But the drawbacks of having a much larger central obstruction (causing reduction of contrast) and the inability to utilize longer focal ratios for certain objects, led us to design a multi-element **combination focal reducer and field corrector lens** accessory. **The results are astonishing both visually and photographically.**

Buying a Celestron along with this special lens element allows you to have a dual focal ratio instrument with no sacrifice in image quality. Diffraction-limited optics with the industry's highest transmission means you're buying and using the BEST Schmidt-Cassegrain.

Jim Riffle of Astro Works quotes, "Visually, I used the reducer on the Ultima 8 with a 4mm Ortho while viewing Saturn. At over 300x, it was tack sharp. Cassini's division couldn't have been crisper. At low power the C8 becomes an RFT instrument easily equalling or surpassing coma-corrected Newtonians in full field image quality. Off-axis guiding the C8 with this reducer allowed for numerous, uncommonly sharp guide stars. The low power views through the C14 were awesome!" One of Jim's astrophotos is shown above - compare it to competitive product photos!

reducer/corrector- f/6.3 #94175

- **4 element design**
- **41mm clear aperture**
- **Fully multi-coated**
- **1-1/2" dia. field size on 35 mm film**
- **f/6.3 (for C8/C11), f/7 (for C14)**
- **Works with all past & present Celestron C8's, C11's & C14's**
- **2-1/2 times reduction in exposure time as compared to f/10**
- **Attaches directly to the rear opening on C8 (to the reducer plate on C11/C14)**
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